PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI. MAY, 1897. NO. 155.

Stated Meeting, February 19, 1897.

The Treasurer, J. SERGEANT PRICE, in the Chair.

Present, 23 members.

Correspondence was submitted and letters of envoy and accessions to the library were reported.

A bronze medal, commemorative of its Sesqui-centennial, was presented by Princeton University, for which the thanks of the Society were given.

The following deaths of members were announced:

Dr. Henry Hartshorne, of Philadelphia, at Tokio, Japan, on February 10, 1897, æt. 73.

Hon. J. Randolph Tucker, of Lexington, Va., on February 13, 1897, æt. 73.

Prof. Henry D. Gregory, of Philadelphia, on February 14, 1897, æt. 77.

The stated business of the meeting being the election of members, the nominations were spoken to, and the ballots cast, Secretaries Hays and Prime acting as Tellers.

Prof. Cope presented a "Communication on Some Paleozoic Vertebrata from the Middle States."

A communication was laid before the Society, consisting of a sketch of an act to be presented to the Legislature of Pennsylvania setting apart three areas of 40,000 acres each on the water sheds of the Delaware, Susquehanna, and Ohio, for a State Forestry Reservation.

PROC. AMER. PHILOS. SOC. XXXVI. 155. K. PRINTED JUNE 15, 1897.

Judge Sulzberger moved that the American Philosophical Society heartily approves of the purpose to secure State Forestry Reservations for the Commonwealth and recommends to the Legislature the passage of the measures necessary to carry this purpose into effect. Adopted.

The Tellers reported that the following nominees had been elected to membership:

2302. Morris Jastrow, Philadelphia.
2303. Ferdinand J. Dreer, Philadelphia.
2304. William H. Furness, 3d, M.D., Wallingford, Pa.
2305. Edwin Grant Conklin, Ph.D., Philadelphia.
2306. Horace Howard Furness, Jr., Philadelphia.
2307. H. M. Hiller, M.D., Philadelphia.
2308. John Sartain, Philadelphia.
2309. Henry Trimble, St. David's, Pa.
2310. George W. Biddle, Philadelphia.
2311. Alexander C. Abbott, M.D., Philadelphia.

The meeting was then adjourned by the presiding officer.

Stated Meeting, March 5, 1897.

The Vice-President, Dr. PEPPER, in the Chair.

Present, 12 members.

Prof. Trimble and Dr. Abbott, newly elected members, were presented to the Chair, and took their seats.

Acknowledgments of election to membership were received from Prof. Morris Jastrow, Jr., Mr. Ferdinand J. Dreer, Prof. Edwin Grant Conklin, Dr. H. M. Hiller, Prof. Henry Trimble, Mr. George W. Biddle and Dr. Alexander C. Abbott.

Donations to the Library were reported.

Prof. Arthur W. Goodspeed exhibited some recent radiographs, and made a comparison of them with the work of a year ago.

Dr. Pepper, Mr. Ingham and Dr. Hays participated in the discussion following Prof. Goodspeed's remarks.

Stated Meeting, March 19, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, 12 members.

Acknowledgments of election to membership were received from Mr. John Sartain, Dr. W. H. Furness, 3d, Mr. H. H. Furness, Jr.

The announcement of the decease of the following members was made and obituary notices of them were ordered to be prepared:

Mr. Arthur Biddle, at Atlantic City, on March 8, æt. 44.

Prof. James J. Sylvester, at London, Eng., on March 15, æt. 83.

Prof. George Stuart, at Philadelphia, on March 16, æt. 66.

Donations to the Library and Cabinet were announced, and in connection with the latter, Dr. Morris moved "That Mr. Patterson's deposit of the Illustrated Catalogue of the Peale Collection of the Stone Age to be returned on his demand, be accepted, and that it be placed in charge of the Curators." Adopted.

Prof. Edwin J. Houston and Dr. A. E. Kennelly read a paper entitled "The Insulating Medium surrounding a Conductor, the Real Path of its Current."

Dr. Hays moved that a Committee of five members be appointed to consider and report upon the advisability of the Society publishing a Calendar of the Franklin Correspondence in its possession, and if found advisable, to recommend a plan for such a calendar and its publication. Also to consider and report on the historic relation to the original document of the manuscript copy of the Declaration of Independence sent by Jefferson to Richard Henry Lee, and now in the possession of this Society, and whether its historic importance renders desirable its reproduction by the Society. Adopted.

Dr. Pepper, Judge Mitchell, Mr. Carson, Mr. Stone and Dr. Bache were appointed the committee under the above resolution.

THE INSULATING MEDIUM SURROUNDING A CONDUCTOR THE REAL PATH OF ITS CURRENT.

BY EDWIN J. HOUSTON, PH.D., AND A. E. KENNELLY, SC.D.

(*Read March 19, 1897.*)

Up to the commencement of the present century our knowledge of electricity and its action was almost entirely confined to the phenomena of electric charges and their dissipation by discharge. The conception of an electric current as a steady condition of discharge had not then been clearly apprehended. It was observed that dissimilar bodies, when placed in contact with, or rubbed against, each other, manifested electric excitation. It was assumed that the electric charges thus acquired resided upon the exterior surfaces of the charged bodies, and that charged bodies evidenced mutual electric attractions and repulsions at a distance. The idea of action at a distance was, therefore, inseparably connected with early conceptions of electricity and electrical phenomena. Action at a distance was explained by some on the hypothesis that an electrified body emitted an invisible electric effluvium which acted upon electrified bodies in its vicinity. It was observed that electric charges were transmitted through certain bodies called conductors, and failed to be transmitted through other bodies called non-conductors or insulators. In a similar manner the phenomena of magnetism, as developed up to the commencement of the present century, pointed to the seeming attraction and repulsion of magnetic poles. According to the views then existing, a magnet was a skeleton of iron or steel for supporting two opposite poles at its extremities. These poles manifested peculiar properties to which the intervening skeleton was considered as merely subordinate. This magnetic action at a distance, by which the magnetic poles of the earth were assumed to direct the compass needle, was supposed by some to be effected through the medium of a magnetic effluvium emitted from the poles of the magnet. Up to the commencement of the present century, therefore, electric and magnetic phenomena were studied apart, and each was accredited with the possibility of action at a distance, except in so far as some physicists endeavored to explain such action by the intervention of material electric and magnetic effluvia. About the commencement of the present cen-

tury, the discovery of the voltaic pile brought to the notice of electricians the development of an electric current, or a steadily maintained discharge. The phenomena produced by the electric current were apparently so different from those produced by electric charges that they were at first believed to be essentially distinct. The electric current could only be produced when a complete conducting path or circuit was provided, any breach of continuity in the conducting circuit immediately interrupting the current flow. Consequently, it appeared that the electric current passed through the conductor, usually a metallic wire, in a manner somewhat similar to that in which a liquid flows through a pipe. Moreover, the electric current was apparently restricted to the conductor, and could not pass through the insulating medium surrounding it.

In 1820, not long after the discovery of the voltaic pile, Oersted announced the first known connection between electricity and magnetism. Using the usual language, when a wire, through which an electric current is flowing, is brought into the neighborhood of a suspended magnetic needle, the poles of the needle are attracted and repelled in a manner depending upon the direction of the current and its position relatively to the needle. Here an electric current apparently acted at a distance on the needle; for, in the insulating medium, usually the air, in which the magnet was suspended, no electric current could flow, and yet the magnet's poles could be acted upon at a very considerable distance from the wire carrying the electric current.

Up to the middle of the present century, therefore, the phenomena of electricity, magnetism and electromagnetic action, suggested both action at a distance, and that electric currents pass solely through the mass of a conducting wire independently of the external insulating medium. It is true that the idea of action at a distance was regarded as illogical, and as contrary to the fundamental principles of dynamics, ever since the days of Newton, but despite this unwillingness of physicists, the old notions of actions at a distance continued to be thus passively employed and promulgated, and, even to-day, they still permeate scientific literature. Another reason for the retention of the recognizedly erroneous ideas of action at a distance is to be found in the fact that, up to the middle of this century, all the mathematical processes adopted for dealing with the phenomena of electricity, magnetism and electromagnetic action, tacitly assumed the principles of action at a distance just as

the mathematical processes of astronomy at the present time tacitly assume the same law, without pretending to explain the mechanism by which such action may be conveyed. Consequently, it was only too easy for students to imbibe, with the mathematical ideas for studying quantitative electromagnetic facts, the fundamental hypothesis of action at a distance upon which this idea was based. Thus the mechanical forces existing between charged electrified bodies, between magnet poles, between electric currents, or between electric currents and magnets, were all referred to the mutual actions of elementary portions of imaginary electric or magnetic substances, each of which exerted an influence proportional to its quantity, and inversely proportional to the square of its distance from the element acted on. About the middle of the present century, Faraday first paved the way for a change in our views on these questions. He suggested the theory that an electrified body or a magnet did not emit any material effluvium, but exerted an influence on the invisible medium in its vicinity; namely, the universal ether; that this influence was of the nature of a stress, and that the ether surrounding an electrified or magnetized substance was in some manner strained along certain directions which he called lines of force. Consequently, an electrified body produced lines of electric force along which the ether was strained, while a magnetized body similarly produced lines of magnetic force along which the ether was strained, but in a manner different from electric strain. It was this strained ether that connected the electrified or magnetized bodies with bodies in their neighborhood, and permitted attraction and repulsion to be set up between them without necessitating any action at a distance.

Clerk Maxwell developed the ideas of ether strains and stresses mathematically. While retaining the original methods of quantitatively determining the mechanical actions between electric and magnetic bodies, by summing up the effects of all the elements of those bodies on each other, in reference to the inverse squares of the distances, he developed, at considerable length, the action of the intervening medium, and showed how the strain in such medium could produce the mechanical effects observed. In the treatment of this subject he noticed that a disturbance of the electric or magnetic condition of the ether was controlled by a formula similar to that which controls a disturbance in an elastic solid. He was, therefore, led to believe that electromagnetic disturbances in the

ether were propagated in all directions like disturbances in an elastic solid, and were, therefore, transmitted in waves. Maxwell, therefore, was the discoverer of the probability of electromagnetic waves in ether. He also suggested that light might be a purely electromagnetic phenomenon of very high frequency, and adduced experimental evidence in favor of this belief. The actual existence of these electromagnetic waves has since been abundantly demonstrated by Hertz and many others. Though invisible to the unaided eye, electromagnetic waves can be traced by the aid of sensitive electromagnetic apparatus constituting what has not been inaptly styled the electric eye.

As the result of both the experimental and mathematical work of the latter half of the present century, especially that of Mr. Oliver Heaviside, it is now believed that electric currents are transmitted as electric waves through the ether surrounding a conductor, being guided by the conductor, but not transmitted through it.

Notwithstanding the fact that the more modern views have been in existence for upwards of thirty years; that their truth is practically undisputed, and that, on the contrary, within the last ten years, strong experimental evidence has been adduced in their behalf, yet both the old phraseology and the old methods of treatment are still almost universally employed even in the modern text-books of the day.

In view of the preceding facts, the authors consider that a brief description of the manner in which an electric current is now believed to be transmitted, may aid in disseminating the more modern views.

All electric, magnetic or electromagnetic phenomena are now believed to be referable to two conditions of stress in the ether, one of which is called *electric flux*, and the other, *magnetic flux*. The exact nature of both is unknown. Though invisible, the presence of each may be manifested in a variety of ways. So intimately are the electric and magnetic fluxes correlated, that any disturbance in one immediately calls the other into existence. Electric flux exists between two electric charges. Thus, a positively charged sphere, situated at rest in a room, radiates streams of electric flux, towards all parts of the room, along lines called *stream lines*, which may be readily mapped out. The ether is strained or disturbed in some manner along these stream lines. So long as the charge on the insulated body remains at rest, electric flux will per-

meate the air and ether in the room, but there will be no magnetic flux present, except that due to the earth's magnetism. As soon, however, as any motion occurs in an electric flux, either by moving the charge on the body, or by causing it to increase or decrease in density, the disturbance in electric flux temporarily produces a magnetic flux; and, generally speaking, any variation or motion of electric flux produces magnetic flux.

A permanent magnet produces magnetic flux, both in its substance and in the space surrounding it. So long as the distribution of magnetic flux remains quiescent, no electric flux is produced. As soon, however, as any change takes place in the magnetic flux, either by bodily moving the magnet, or by weakening or strengthening the magnet, electric flux is temporarily produced. Generally, any variation or motion of magnetic flux produces electric flux.

Magnetic flux is always circuital, or is distributed in stream lines which form closed curves, or have reëntrant paths. Electric flux, when established between opposite electric charges, is not circuital, but terminates at one end in one charge, and at the other end in the opposite charge. When, however, electric flux is established by magnetic disturbances in a space free from conductors, it is circuital, like magnetic flux.

Both electric and magnetic flux possess both direction and polarity; that is to say, each is developed along definite stream lines, and each possesses different properties up and down such stream lines. An analogy is presented mechanically in a stream of water. Water in a river flows in stream lines, and is directed in its motion down stream. In the case of electric flux the polarity is manifested by what are called positive and negative charges, these charges being developed where the electric flux terminates. In the case of magnetic flux the polarity is manifested by what is called north-seeking poles and south-seeking poles. These poles are developed where the magnetic flux terminates on the magnet. For this reason electric flux is conventionally assumed to leave a positive charge and, to terminate, on arrival at a conductor, at a corresponding negative charge. This, while being a purely arbitrary assumption, is, nevertheless, advantageous in fixing ideas. Similarly, magnetic flux is assumed to issue from a magnet at its north-seeking pole and to reënter it at its south-seeking pole. This assumption is also purely arbitrary.

Both electric and magnetic fluxes contain energy. Work must be charged on the flux to establish it, and this work is liberated when the flux disappears. The energy in the ether varies as the square of the flux density, so that if we crowd uniformly twice as much flux through a given area of cross-section, we quadruple the amount of energy which resides in that portion of space per cubic inch, or per cubic centimetre.

The electric transmission of power consists in transferring electric and magnetic flux to a distance and allowing these fluxes to be expended in liberating, at the receiving end of the line, the energy they contain. An electric generator is a machine for producing electric flux and thus transferring electric energy to the ether. This electric flux, or energized condition of the ether, is transferred to a distant point along wires, the ether being deprived of its energy at the receiving end of the line. The electric flux is there absorbed, and the work which was expended by the generator is recovered to a greater or less extent.

The electric flux is transmitted from the generator to the receiver, through an insulating medium, being guided on its passage by a pair of conductors, extending all the way from the generator to the receiver. Such a pair of conductors, with the associated insulating medium between them, is called an *electric circuit*. The curious fact exists that while the old conception of an electric circuit held that the electric current passed through the conductors, and was retained in position on those conductors by reason of the insulating medium surrounding them, the modern view holds, on the contrary, that the electric current flows through the insulating medium and is held in position, or guided to its destination, by the two conductors. In other words, the modern theory completely reverses the relative functions of the insulator and the conductors in the old theory.

There are three standard types of pairs of conductors, and their associated, intervening, insulating medium; viz.,

1. An aërial conductor, such as a telegraph wire, supported sensibly parallel to the surface of the ground. Here the wire forms one conductor, the ground the other conductor, while the ether associated with the air between them is the medium through which the electric current flows.

2. Subterranean or submarine conductors separated from the surrounding conducting earth or water by a uniform layer or coating of insulating material. Here one conductor is formed by the

interior wire, while the other conductor is the sheath of metal, liquid or ground, and the medium through which the electric current flows is the ether in the insulating coating of rubber, gutta-percha, paper, etc., with which the interior conductor is invested.

3. A pair of overhead wires supported sensibly parallel to each other, on suitable insulating supports; as, for example, a pair of telephone or electric-light conductors. Here the two wires are the conductors, and the medium through which the electric current flows is the ether in the air between them.

When an electric source is connected to any such pair of conductors, an electric flux is established in the insulator between them; or, more correctly speaking, in the ether permeating the insulator. The density of the electric flux, or the quantity of flux per normal square centimetre, will depend upon the nature of the insulator, on its dimensions, and on the electric pressure or voltage of the source. An increase of voltage is attended by a proportional increase in the density of the electric flux; while an increase in the thickness of the layer of insulating material between the conductors diminishes the density. Figs. 1, 2, 3, are diagrams of the distribution of electric flux for the three types of circuit mentioned.

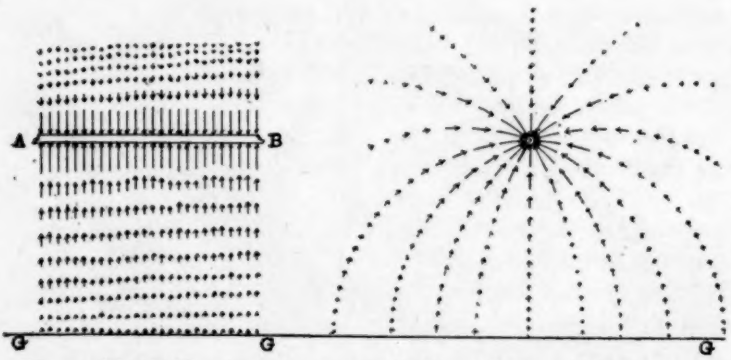


FIG. 1.—Electric Flux Surrounding an Aërial Wire with Ground-Return Circuit.

In Fig. 1, AB, represents the aërial wire, and GG, the ground. The flux stream-lines are represented on the right-hand side in a plane perpendicular to the wire. These stream lines are arcs of circles, on the supposition that the ground, GG, is conducting, and has a level surface, such as might be presented by the surface of water in a lake. On the left-hand side the flux is represented as

being distributed in straight lines; *i. e.*, in sections of planes, perpendicular to the wire and to the ground. The wire being negatively charged, by convention the flux streams converge towards it.

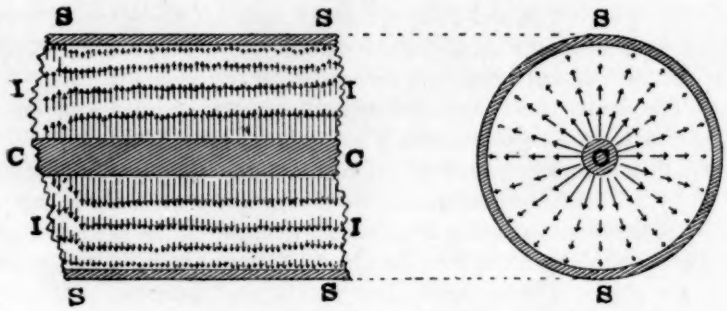


FIG. 2.—Electric Flux Permeating Insulator of Cable.

In Fig. 2, CC, is an insulated conductor, usually of copper, separated from the conducting sheath SSSS, which may be of lead or other metal, by the cylindrical insulating jacket IIII. Here the flux is represented as emerging from the wire which is, therefore, regarded as positively charged. The density of the flux is greatest in the vicinity of the interior conductor, and diminishes uniformly as we proceed towards the sheath. This is represented diagrammatically by the length of the flux arrows. On the left-hand side the flux is seen to be distributed in planes perpendicular to the length of the cable.

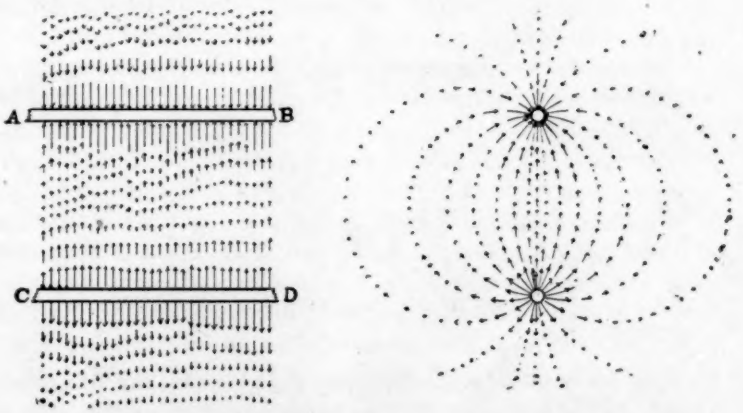
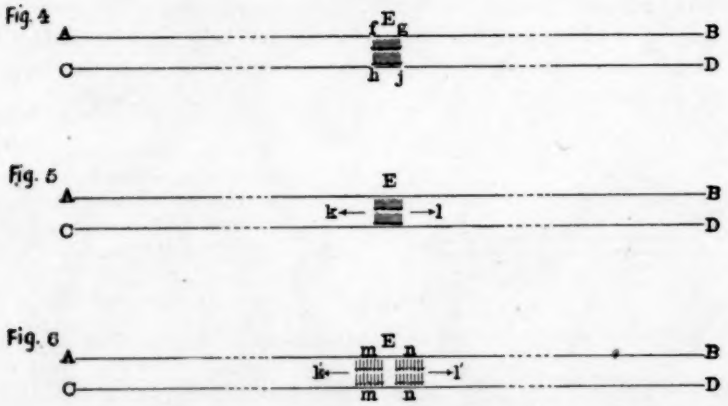


FIG. 3.—Electric Flux Permeating Insulator between Two Parallel Wires.

Fig. 3, represents two parallel wires, AB and CD, the latter positively and the former negatively charged. Here the flux issues from the wire CD, and converges upon the wire AB, in curves, which are all arcs of circles. The flux density is greatest in the neighborhood of each wire and least in the intermediate portions. On the left-hand side, the longitudinal section shows that the flux is distributed uniformly in planes perpendicular to the two wires.

The electric flux, which thus permeates the insulating medium, persists as long as the insulation is maintained, even in the absence of the original electric source. Thus, if a pair of wires be perfectly insulated from each other, and are charged as represented in Fig. 3, by connection to an electric source; then, so far as is known, the electric flux, which will be developed between them in the insulating medium, will be indefinitely maintained, although in practice there is always sufficient leakage to permit the charge to gradually disappear.

In order to study the electric transmission of power over a circuit, we may suppose that a pair of perfectly conducting wires exists extending between two cities. These conductors may be, say, of the third type; *i. e.*, may consist of a pair of parallel wires supported in air. Let AB and CD, Fig. 4, represent such a pair of conductors



FIGS. 4–6.—Movement of Electric Flux in Circuit of Perfect Conduction and Insulation.

between the terminal stations AC, on the left hand, and BD, on the right. At the middle of the line E, we may suppose that suitable

short lengths of each of the two wires; namely, fg and hj, each one metre long, are insulated from the rest of the system, and electrically charged by a momentary connection to a dynamo or other suitable source, to a pressure of say, 1000 volts. An electric flux will thus be established between the two short lengths of wire of the type represented in Fig. 3, and shown in Fig. 4, by the arrows; fg, being positive, and hj, negative. Strictly speaking, the flux disturbance would not remain in parallel planes at the ends of the short lengths, but would bulge outwards considerably, from the ends; but this peculiarity is of no consequence to what follows, and we may, therefore, suppose that the simpler geometrical distribution is preserved. If the metre lengths at E, be perfectly insulated from each other, the block of electric flux resident in the ether between them would be indefinitely maintained at 1000 volts pressure.

Suppose, however, that at some instant of time the discontinuities existing between the metre lengths of the conductors and the rest of the system are suddenly bridged over. In other words, the metre-lengths are connected electrically at both ends to the rest of the circuit. Then instantly the flux tends to rush towards the ends of the circuit as represented by the arrows k and l, in Fig. 5. The metre block of flux instantly subdivides into two metre blocks, each under 500 volts pressure, and each with half the original density and, therefore, one-quarter of the original energy. At the same time, the moment that the flux commences to run, a magnetic flux distribution is brought into existence; for, as we have already mentioned, a motion of electric flux can never occur without producing magnetic flux. While then the metre block of Fig. 5, divides into two separate metre blocks, moving in opposite directions, as in Fig. 6, each block becomes invested with magnetic flux in the manner represented in Fig. 7. Here the curves of magnetic flux distribution, indicated by arrows, are circles eccentric to the wires. One-half the energy of each moving block is electric and is resident in the electric flux, and one-half is magnetic and is resident in the magnetic flux. It will be observed that the magnetic flux is so directed as to pass through the loop formed by the two wires, in planes perpendicular to the wires. Moreover, the curves of magnetic flux stream-lines are all perpendicular to the curves of electric flux stream-lines, which, already shown in Fig. 2, are here represented by dotted lines. The magnetic flux at each point is due to the movement of the electric flux through the ether at that point,

and is not due, as the old theory supposed, to an assumed current in the wire. The passage of the electric flux over the wires constitutes a momentary electric current, which in this case would have a strength of roughly two amperes. The velocity with which the flux blocks move in Fig. 6, is the velocity of light in air; approximately, 300,000 kilometres per second. If the distance from E, to the ends of the wires is exactly 300 kilometres each way, the metre blocks of

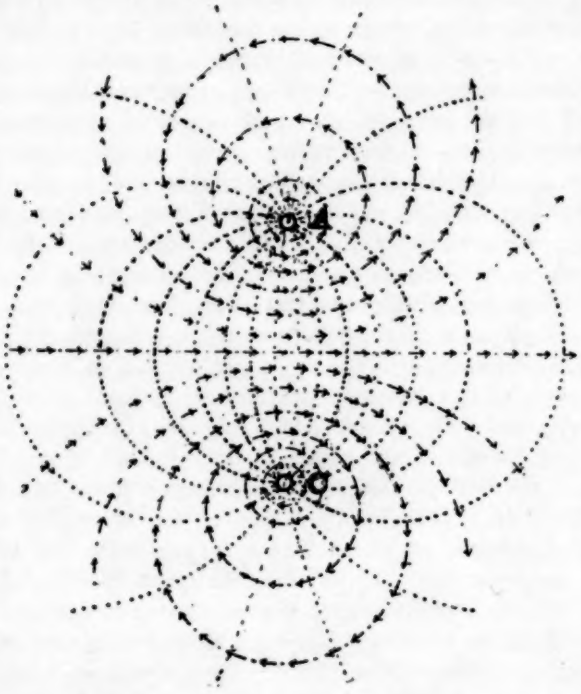
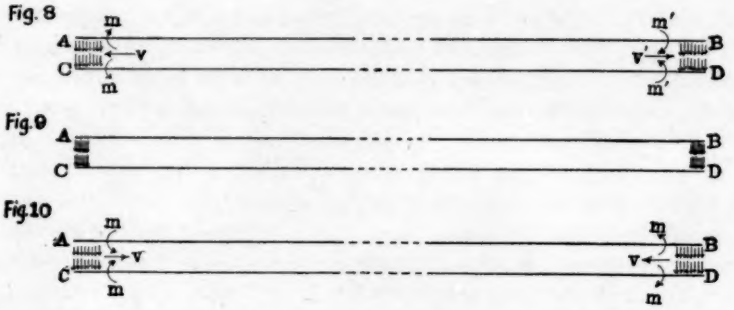


FIG. 7.—Magnetic Flux Accompanying Moving Electric Flux between Two Parallel Wires.

flux will traverse this distance in $\frac{1}{1000}$th of a second. The metre blocks will, therefore, pass by any particular point on the line in $\frac{1}{300,000,000}$th of a second, and the electric current, which this flux rush constitutes, would, therefore, have this duration at any particular point.

Fig. 8, represents the metre blocks of flux in the act of arriving at the termini of the line. The two conductors are open-cir-

cuited, or insulated, at both ends. The arrows v and v′, represent the direction in which the blocks have arrived, and the curved arrows mm, and m′m′, represent the direction of magnetic flux which has been generated by the movement of each block, and which has been carried bodily along with the moving blocks. If the original metre block of flux in Fig. 4, represents an amount of energy resident in electric flux, amounting to say 1000 ergs, then each of the two metre blocks into which this is divided, assuming no dissipation of energy, carries with it 500 ergs, 250 in magnetic flux and 250 in electric flux.



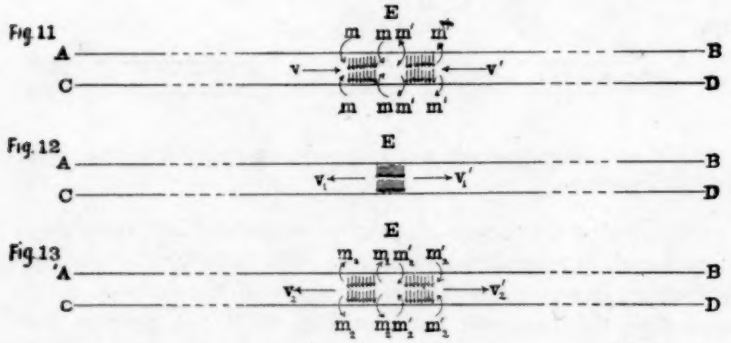
FIGS. 8–10.—Reflected Movement of Electric Flux in Circuit of Perfect Conduction and Insulation.

On arrival at the termini, the flux is compressed into a half metre at each end, as represented in Fig. 9. The density of electric flux is doubled, as represented by the closeness of the arrows. At the same time the magnetic flux vanishes, while the pressure rises momentarily from 500 to 1000 volts. There is, therefore, half the volume of flux with twice the density; and, therefore, four times the voluminal electric energy, but no magnetic energy. Consequently, there remains 500 ergs of purely electric energy in each block.

Fig. 10, represents the conditions of affairs immediately afterwards. Here the blocks expand again into metre lengths and are reflected from the termini, or move back towards the centre of the line. The magnetic flux reappears, but in the reversed direction, as shown by the curved arrows. The electric flux retains its original direction from the upper to the lower wire, and the pressure has fallen from 1000 to 500 volts as before. The current represented

by the flux rush is, therefore, reversed in direction, since the magnetic flux, by which it is measured, is reversed, but the electric potential difference, as measured by the density of electric flux, remains unaltered. The two metre blocks now rush towards the centre of the line with the speed of light. They may be considered as solitary waves of light, that is to say, disturbances traveling with the velocity of light waves, but not periodic, and leaving the medium quiescent the moment they pass by.

After the lapse of another $\frac{1}{1000}$th of a second, the two metre blocks, which will again arrive at E, the middle of the line, as shown in Fig. 11, where the two arrows v and v′, indicate that the blocks are about to collide. The curved arrows show that the magnetic flux is oppositely directed in the two blocks, those on the left-hand side at mm, being directed into the loop, as seen by the observer, while those on the right-hand side at m′m′, being directed out of the loop.

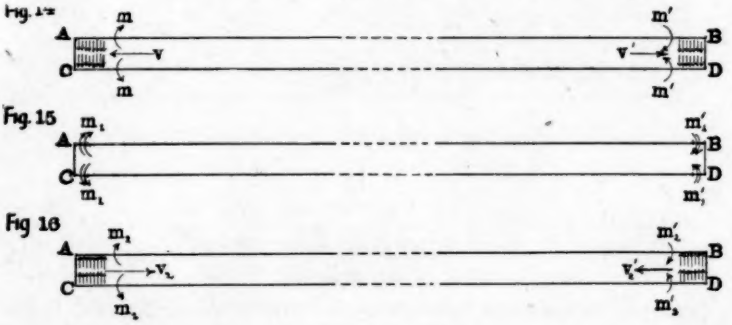


FIGS. 11–13.—Collision of Electric Flux Waves in Circuit of Perfect Conduction and Insulation.

In Fig. 12, the metre blocks are represented as having collided; they have merged together and mutually annulled each other's magnetic flux. Consequently, there is no magnetic energy. On the other hand, the density of electric flux being doubled, there will be four times the electric energy per cubic centimetre. Consequently, there are 1000 ergs of electric energy in the single metre block at 1000 volts pressure, just as in the original condition before the start, in Fig. 5. The two blocks, however, pass completely through each other, appearing on the opposite sides.

Fig. 13, represents this condition of affairs. Here the two blocks have passed completely through each other and once more rush out with the velocity of light towards the ends of the conductors, which they will reach in the $\frac{1}{1000}$th of a second. This process of meeting in the centre, separating, reaching the ends, and being reflected therefrom, will repeat itself indefinitely in cycles which take $\frac{4}{1000}$th of a second to complete, the current direction reversing at each reflection from the ends. In this case of perpetual motion, we have assumed that there is no dissipation of electromagnetic energy, there being no leakage between the two conductors, and perfect conduction in the two wires.

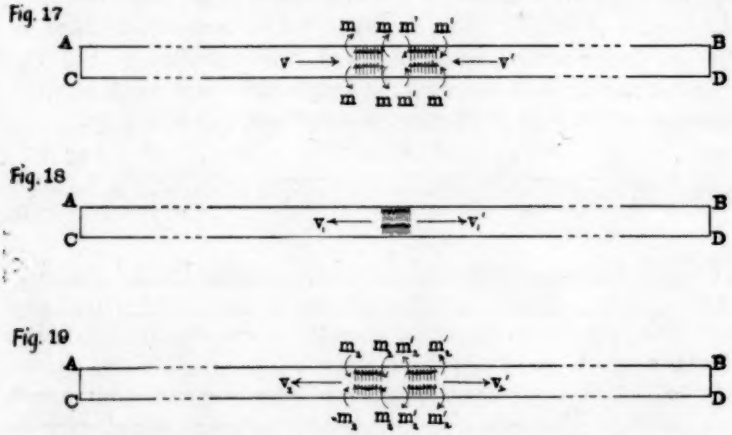
We have hitherto assumed that the two wires AB and CD, were open-circuited, that is insulated from each other at their termini. We now suppose that they are short-circuited; that is directly connected at the termini. Let the metre block of flux be started from E, the centre of the line, as in Fig. 5. Then, in $\frac{1}{1000}$th of a second, the two metre blocks, into which the original block divides, will rush over the intervening 300 kilometres, and will reach the ends of the line as shown in Fig. 14, the arrows v and v′, indicating the direction in which the blocks have arrived, and the curved arrows representing the direction of accompanying magnetic flux. In this case, instead of the electric density being doubled, the electric flux vanishes completely as soon as the magnetic flux is compressed into half a metre of length. The magnetic flux is, however, doubled in density, as represented by the doubled curved arrows of Fig. 15. Here the energy is all magnetic, and each half-metre block of magnetic flux at the ends of the line contains 500 ergs of energy.



FIGS. 14–16.—Reflected Movement of Electric Flux in Circuit of Perfect Conduction and Insulation, Short-Circuited at Termini.

Fig. 16, represents the condition of affairs the moment after the disappearance of electric flux. Here the electric flux has reappeared in the form of the two metre blocks, which take their departure towards the centre of the line, but now it will be observed, by the direction of the flux arrows, that the electric flux is reversed in direction. Consequently, the lower wire has become positive and the upper wire negative; or, the 500 volts difference of potential between the wires is reversed in direction by reflection from the short circuits at the termini. The magnetic flux possesses its original direction as shown by the curved arrows. Consequently, the momentary current, which is constituted at any point along the line by the flux rush past it, does not change direction when the pulse comes back reflected.

The two reflected metre flux-blocks rush with the speed of light towards the centre of the line. The condition of affairs just before they meet is represented in Fig. 17. The magnetic flux is oppositely directed in the two blocks. Consequently, when the two blocks merge, as shown in Fig. 18, the magnetic flux is annulled, but the electric density is doubled. We have, therefore, in Fig. 18, 1000 ergs of energy in electric flux, situated in a metre block, but with the opposite direction of potential to that which exists in the original state of Figs. 4 and 5.



FIGS. 17–19.—Collision of Reflected Electric Flux Waves in Circuit of Perfect Conduction and Insulation Short-Circuited at Termini.

The two metre blocks then separate out by passing through each

other as shown in Fig. 19, where the two blocks are seen to be withdrawing from each other with the speed of light. They again rush to the termini of the line, where they undergo reflection with reversal of electric flux and persistence of magnetic flux. This condition of reflection and collision would continue forever, under the conditions assumed.

We have hitherto assumed that the insulator insulated perfectly and the conductor conducted perfectly. Neither of these two conditions is attained in practice. We will first assume that there is imperfect insulation in the insulator, with perfect conduction in the wires. For convenience, we may change the type of circuit to the second; namely, a cable composed of a central wire and annular external conducting sheath. This is represented in Fig. 20,

Fig 20

Fig. 21

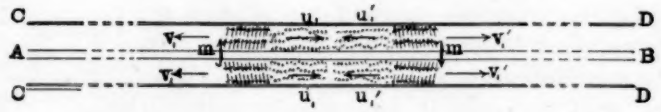
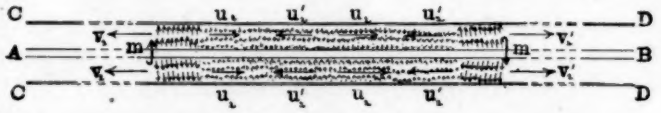


Fig. 22



FIGS. 20–22.—Movement of Electric Flux in Cable of Imperfect Insulation and Perfect Conduction.

where AB, is the central conductor and CD, CD, the external conducting sheath. Let us suppose that a metre block of flux, at 1000 volts, is, as before, called into existence, and released from the centre of the line. The flux block immediately starts with the velocity of light in the ether of that particular insulator, which may be, perhaps, 200,000 kilometers per second, instead of 300,000 kilometers per second, as in free ether. The block, as before, subdi-

vides into two metre blocks, each with half the density and each with its attendant magnetic flux, as represented by the straight and curved arrows of Fig. 21. Instead, however, of pursuing their paths as sharply defined blocks, the two blocks are subjected to attenuation by leaving stragglers or remnants along the road, since the insulator is somewhat leaky. That is to say, the path through which they pass is strewed with reflected or oppositely directed electric flux, of reduced density, which immediately turns around and moves back towards the centre of the line with the velocity of light in that medium. Consequently, the two metre blocks undergo a process of decay; their density is diminished; their energy is dissipated in the insulator as heat, and in supplying the straggling reversed fluxes; and the distribution, instead of being in planes perpendicular to the cable, is bent backwards in a manner which is exaggerated in Fig. 21. In fact the flux behaves as though it got entangled in the insulator instead of moving freely through it, and by reason of the entanglement, a number of shreds or straggling particles are detached from the advancing main body. If the leakage be sufficiently great, the blocks of flux may be completely dissipated before they arrive at the termini of the line, the degree of attenuation depending entirely upon the amount of leakage.

Fig. 22, represents the condition of affairs at a later stage of the first outward movement of the flux blocks. Here v_2 v'_2, represent the movement of the heads of the columns; u_2 and u'_2, represent the backward movement of the stream of stragglers thrown off by the heads in the course of their motion. Consequently, the entire field between the two separating heads is filled with a confused and straggling mass of attenuated flux, and a very complex state of affairs is reached. The original blocks are entirely absorbed after they have traveled a greater or less distance.

We may next assume that the insulator insulates perfectly, but that the wires do not conduct perfectly. This is a condition which is very nearly represented in many practical cases. In Fig. 23, the metre block of flux starts from the centre as before. The interior conductor being positively, and the sheath negatively, electrified. The curved arrows represent the direction of accompanying magnetic flux, produced as soon as the motion takes place. Here the imperfect conduction of the wire sets up a series of straggling reflections of electric flux, in the same direction, however, as that in the moving blocks, instead of the oppo-

site direction, as in Figs. 21 and 22. The electric flux is bent from the perpendicular in the direction of motion, as represented in exaggeration at Fig. 24. Consequently, the metre blocks are subjected to a process of attenuation or decay, by throwing off attenuated electric flux as they advance, the straggling flux so thrown off immediately commencing to rush backwards with the velocity of light in the medium as represented by the arrows u_1 u'_1. The metre blocks, therefore, lose definition as they advance, becoming weaker and weaker, the energy being lost into the conductor and into straggling flux. If the wires conduct sufficiently imperfectly, the two metre blocks may be completely absorbed before they reach the terminals of the line, the degree of attenuation depending entirely upon the degree of imperfection in conducting power, for a given electric cable; *i. e.*, a given geometrical distribution of insulating medium. The fact of imperfect conduction, may be represented roughly by supposing that the flux, instead of slipping freely along the surface of the conductor, becomes entangled in the surface of the same, and friction between the base of the moving flux and the surface of the wire detaches some of the flux and leaves the detritus in the pathway.

Fig. 23

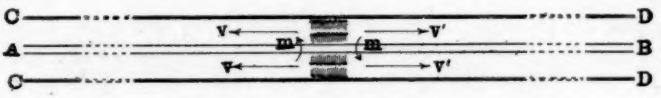


Fig. 24

Fig 25

FIGS. 23–25.—Movement of Electric Flux in Cable of Perfect Insulation and Imperfect Conduction.

Fig. 25, represents the condition of attenuation at a later stage.

Here the original metre blocks have diminished considerably in density, and in their stock of energy, their motion being indicated by the arrows v_2 and v'_2. u_2 and u'_2, are arrows representing the motion of the straggling flux, or *tails*, as they have been called, thrown off by the advancing blocks. After a certain distance has been traversed by these blocks they become completely absorbed and the tails only remain, the subsequent motion being very complex.

All the best electric conductors with which we are acquainted; namely, the metals, conduct imperfectly at the temperatures at which they exist on the earth. It has been shown that pure copper would apparently conduct to perfection, or have no electric resistance, at the temperature of absolute zero, or — 273° C. It is possible that some means may eventually be found to artificially produce in copper, at ordinary temperatures, the electric conducting power it possesses at or near the absolute zero of temperature, but at the present time we have to content ourselves with the comparatively imperfect conducting power of copper, which is practically the best electric conductor available. Consequently, we cannot attain in practice to the distortionless transmission of electro-magnetic waves such as represented in Figs. 4 to 19.

It is, however, possible to so unite imperfect insulation with imperfect conduction; *i. e.*, leakage with conductor-resistance, as to cause the tailings due to leakage to exactly annul the tailings due to conductor resistance; for, the comparison of Figs. 20, 21 and 22, with Figs. 23, 24 and 25, will show that these tailings are oppositely directed as regards electric flux, the tailings from leakage being reversed, and the tailings from conductor resistance being similarly directed, to electric flux in the main blocks. A circuit in which the leakage and conductor resistance are so balanced as to leave no tailings, is called a *distortionless circuit*, and no other means of obtaining a distortionless circuit is known at the present time. Although such a circuit is distortionless, since no tailings are left, as the blocks of flux move on without leaving stragglers, yet energy is expended both into the insulator and into the conductor, and, consequently, the fluxes diminish in density and attenuation goes on. This is represented in Fig. 26. Here the metre block of flux is started from the centre of the line as before, the directions being indicated by the arrows. In Fig. 27, the electric flux is seen to have a double curvature, being partly bent outwards and partly bent inwards. Energy is being dissipated sideways into the insulator,

and sideways into the conductor, as the blocks move on. Consequently, the electric density and the accompanying magnetic density are diminishing, but no straggling electric or magnetic flux is left to mark the passage of the blocks. If the original stock of energy was 1000 ergs, the energy which may reside in the two blocks, when they reach the ends of the line, may be, perhaps, only 100 ergs, depending entirely upon the amount of electric resistance in the conductor, and the corresponding amount of leakage which must be given to the insulator in order to balance the same.

Fig. 26

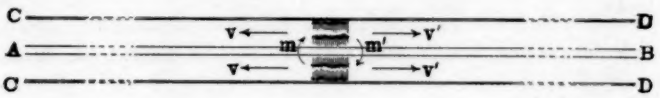


Fig. 27

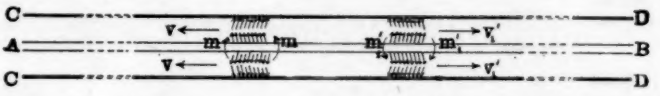


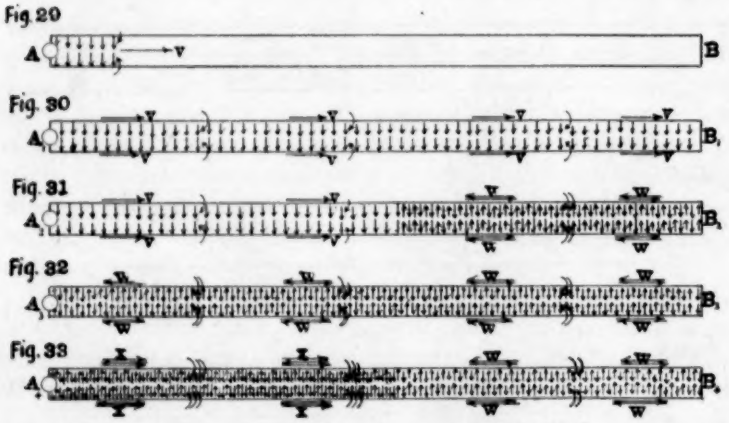
Fig. 28

FIGS. 26–28.—Movement of Electric Flux in Distortionless Cable.

Fig. 28, represents the condition of attenuation without distortion at the later stage in the process.

We have hitherto assumed that only a metre block of electric flux was started from the centre of the circuit, and that this was called into existence in some special manner. We shall now consider what takes place when an electric source, such as a dynamo or battery, is connected permanently between the wires at one end of the circuit. In Fig. 29, a dynamo is supposed to be connected at the end A, the positive pole to the upper wire and the negative pole to the lower wire. The dynamo is assumed to have no resistance, and the distant end of the line is short-circuited at B. The moment the connection is effected, electric

flux is supplied from the dynamo to the insulating medium between the two wires. The rush of electric flux which escapes from the dynamo constitutes the electric current which it supplies, and if a certain imaginary unit quantity of electric flux constitutes a *coulomb of electricity* (the practical unit of electric quantity), then the number of coulombs of electric flux, uniformly supplied per second from the generator, represents the number of amperes of electric current supplied to the circuit. If the pressure of the generator is 1000 volts, then the difference of potential between the wires at A, is 1000 volts, and these two wires we may first assume to be per-



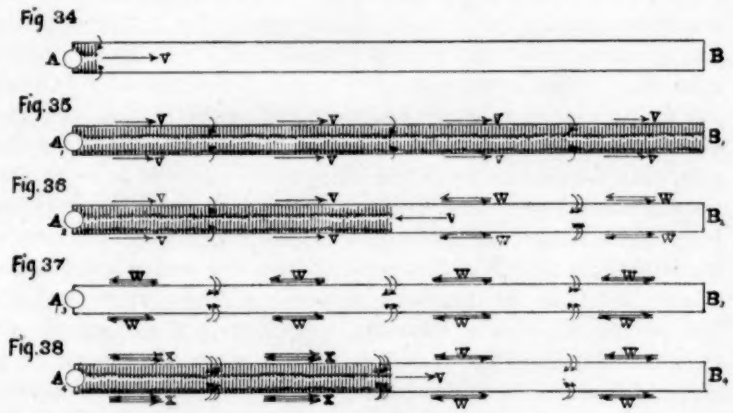
FIGS. 29–33.—Movement of Electric Flux in Closed Circuit of Perfect Conduction and Insulation, when Supplied by a Generator of no Resistance at One End.

fectly conducting. The arrow v, in Fig. 29, represents the initial direction of flux rush, from A towards B. As the flux moves along towards B, with the velocity of light, more flux comes out of the generator. The function of the generator is to supply flux to the insulating medium with which it is connected by the wires. The curved arrows represent the direction of the magnetic flux distribution which everywhere accompanies the moving electric flux.

Fig. 30, represents what takes place by the time that the vanguard of electric and magnetic fluxes has reached the end B. The entire insulator between the two wires is now full of electric flux at the particular density furnished by the dynamo at its pressure. With perfect conduction and perfect insulation there has been no loss of energy, and the magnetic flux and electric flux are just as

dense at B, as they are at A. Reflection with reversal of electric flux takes place at the short-circuit under B_1, so that, as shown in Fig. 31, the vanguard of electric flux can rush back towards A_2, after reflection from B_2, and having the direction represented by the upward arrows, so that, at and near B_2, as much electric flux is now pointing downwards as pointing upwards. There is, consequently, no resultant electric flux near B_2, although there is twice as much electric flux, considered without regard to direction. The magnetic flux is, however, doubled as determined by the reasoning accompanying Fig. 15.

After the proper interval of time has elapsed, the vanguard of electric flux has arrived at A_2, while further flux is all the time pouring out of the dynamo; this condition is represented in Fig 32. It again reflects at A_3, with reversal of electric flux, and advances once more towards B_4, Fig. 33, in the original direction, so that there are now two streams of downwardly directed electric flux, and one stream of upwardly directed flux, leaving as a resultant a single stream, but the magnetic flux is trebled in density. The resulting



FIGS. 34–38.—Movement of Electric Flux in Closed Circuit of Perfect Conduction and Insulation when Supplied by a Generator of no Resistance at One End.

condition is represented in Figs. 34 to 38, which correspond respectively to Figs. 29 to 33. In the first passage between A_1 and B_1, the electric flux fills the entire insulator. In the next passage between A_3 and B_3, Fig. 37, the electric flux entirely vanishes by a process of cancellation of oppositely directed streams, but the mag-

netic flux is doubled. In the third passage from A_1 to B_1, Fig. 38, there is a reappearance of the original electric flux and potential, but with the magnetic flux trebled. In the fourth passage, not shown, there is a disappearance of electric flux with the magnetic flux quadrupled, and so on indefinitely. The current strength, which is always measured by the density of magnetic flux, continually increases by successive leaps at each succeeding passage, but the electric difference of potential between the wires oscillates between the original quantity of 1000 volts and zero. After an indefinitely long period from the start, the current carried by the circuit will be indefinitely great, and this corresponds to what Ohm's law would prescribe in a case of perfect conduction.

Any actual circuit of perfect insulation but imperfect conduction would differ from this case in the fact that the vanguard would be continually subjected to attenuation and distortion, so that it becomes less and less observable in its passage at each successive traverse of the circuit. Finally, after a certain interval of time has elapsed, no further accretion of electric or magnetic flux is perceptible. The rate of dissipation of energy taking place into the conductor, all along the circuit, would then be just balanced by the rate at which further flux energy is pouring into the circuit from the generator. This is the condition which is determined by Ohm's law for the case of a definite resistance and perfect insulation. The effect is to lower the pressure to zero at the distant end of the circuit, and to maintain a uniform strength of magnetic flux distribution all through the circuit. Consequently, when the steady state has been attained under the influence of imperfect conduction and perfect insulation, the potential falls steadily from the source towards the distant end, but the magnetic flux-rush is constant throughout. The electric flux-rush is, therefore, also constant at all parts of the circuit, but some of the rush is directed upwards and some of it is directed downwards, so that at the distant end there is no resultant electric flux, while at the generator end the resultant electric flux is at full density.

This condition is represented in Fig. 39. Here the outrush from the dynamo is indicated by the long flux arrows pointing downwards. As these reach the BD end of the circuit, they are shortened in length, to indicate that the flux density has suffered diminution by attenuation on the journey. The reflected stream is then shown by the reversed arrows, which shorten in length as they return

to the generating end. These are again reflected with reversal, and the shortening process continues from end to end until the stream is no longer perceptible. The contrary movement of the tailings is omitted, for convenience, from the diagram. At E_1, these various stages of the stream are indicated by the horizontal arrows. The first is a long arrow e_1, representing the outgoing stream of full strength. Then come a pair of oppositely directed arrows indicating the passage of the stream on return to AC, with reflection therefrom; then similar pairs of oppositely directed arrows for succeeding returns of the stream, each time weaker and weaker, until finally no longer perceptible. The sum of all these is the first arrow e_1, since all the rest are in pairs which cancel. Consequently, the electric flux at E, has the resultant e_1, or the full strength and density of issue from the dynamo, as shown at E'_1, which represents the voltage or potential difference between the wires at E_1. If the voltage of D, is 1000 volts, E'_1, is 500 volts positive, and E''_1, 500 volts negative.

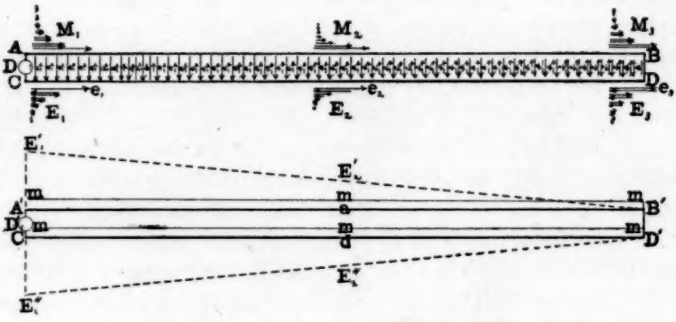


FIG. 39.—Distribution of Electric Flux Streams in Conformity with Ohm's Law in a Perfectly Insulated Closed-Circuit.

Again at the BD end, the electric flux streams are indicated at E_2. First come two opposite arrows e_2, representing the first arrival of the stream and its immediate reflection with reversal. Then follow successive pairs of oppositely directed shortened arrows. The sum of all these is clearly zero, so that the resultant flux density at BD, is zero, and there is no resultant voltage or potential difference. At B'D', therefore, the dotted lines indicating potential fall to zero or join the lines A'B' C'D'.

Again, in the middle of the line at E_2, there is a series of succes-

sive arrows, none of which entirely cancel. Their sum, however, is half e_1, and at ad, the voltage E'_2, E''_2, falls on the dotted lines E'_1 B', E''_1 D'. The same is true for any other point on the line. Consequently, the pressure falls steadily from AC to BD.

It is otherwise, however, with the magnetic flux which undergoes no reversal. The development of this is shown at M_1, M_2 and M_3. The arrows are all of equal length to the corresponding electric flux arrows at E_1, E_2 and E_3, but there is no reversal of direction. The sum of all these sets of arrows is constant at all points of the line, and this condition of constancy in total magnetic flux is represented by the horizontal straight lines m, m, m, m, m, m. In other words, the current strength is constant.

The rate at which energy is being transferred from the dynamo along the circuit past any point is simply the sum of the electric and magnetic energies contained in the various passing streams of flux, the summation being made with regard to the direction of these streams. Thus the first stream may carry past the point considered 1,000,000 ergs in each second, half in magnetic energy, and half in electric energy, the second stream may carry 500,000 ergs backward, the third 250,000 forward, and so on; the resultant stream in this case being 666,667 ergs per second forward, and this is the activity of the circuit at the point considered.

According to these views, therefore, the electric current, which is electric flux-rush, is invariably transmitted with the velocity of light in the ether of the particular insulator considered. But the actual velocity with which an electric impulse travels along the circuit, as measured by the time which elapses between the connection of the source at the generating end and the appearance of energy at the receiving end, always tends to be less than this velocity, because, owing to attenuation and distortion, the first impulse or block of flux may be completely absorbed and dissipated before it can reach the distant end with the velocity at which it travels, and further flux must gradually come up from the source and suffer attenuation and distortion, before the vanguard can finally arrive at the receiving end and perform its allotted function. It is for this reason that a submarine electric cable between say Ireland and America, takes nearly $\frac{1}{7}$th of a second before an electric signal or impulse transmitted from one end will make its first appearance at the other, although the time that an electric wave would take to traverse its length would be only say about $\frac{1}{60}$th second. The original impulse

traveled so far as it went with the velocity of light in the ether of gutta-percha, but the vanguard was completely dissipated and the successive vanguards were attenuated with complete dissipation for a comparatively long time before the distant end could be reached.

It is only on long circuits, such as are afforded by telegraph and telephone wires or submarine cables, that the phenomena of electric transmission with their attendant distortion and attenuation are most clearly evidenced. In the comparatively short circuits employed for transmission of electric light and power, the phenomena of distortion and attenuation of electric and magnetic flux are of little practical importance. Fig. 40, represents the signals sent over

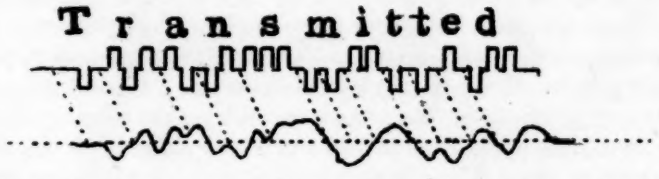


FIG. 40.—Distortion of Signals Received Over Last-Laid Atlantic Submarine Cable.

the last laid Atlantic cable and the corresponding signals which were received at the distant end. The two should be exact facsimiles and should, therefore, be capable of actual superposition if no distortion occurred in the electric impulses. Not only the delay or retardation in the received signals, but also the great distortion which is noticeable, are due entirely to the fact that there is very little leakage in the insulator, while there is very appreciable resistance in the conductor. This cable, laid in 1894, has a published length of 1847.5 nautical miles. The copper conductor offers a resistance of 1.68, or about $1\frac{3}{4}$, ohms per nautical mile, while the insulator has a resistance of 85,000,000,000 ohms in each nautical mile. This cable has a working speed of over forty-five words per minute, which is much faster than any other previously laid Atlantic cable, owing to the greater conductance of the circuit. This cable possesses, of course, enormous distortion, although such distortion does not prevent signals being read until a speed of over 225 letters per minute is attained. If, however, the insulation, instead of being 85,000,000,000 ohms in each nautical mile, were reduced to about 500 ohms in the nautical mile, the leakage tailings would

probably balance the tailings due to imperfect conductance and the cable would be distortionless. The signals received would, therefore, be the exact counterpart of the signals sent, and an indefinitely high speed of signaling should be possible. In respect to absence from distortion, such an Atlantic cable would transmit telephonic speech waves perfectly. It would, however, possess so much leakage that the received signals would be far too attenuated and feeble to perceive. The conductor would only offer at the sending end a resistance of, approximately, 28 ohms, instead of 3108 ohms, the total conductor resistance, and the current strength which would flow from the receiving end to ground would be, approximately, 5×10^{47} times less than the current entering at the generating end. No telegraphic or telephonic instrument at the present time could detect so feeble a current as this. Moreover, if any accident happened to such a cable it would be impossible to localize the position of the fault unless the same occurred within a mile or two of either end. Consequently, the distortionless circuit does not provide at the present time a practical solution for trans-Atlantic telephony. About one hundred miles is, probably, the limiting length of this particular cable, with its good insulation, over which telephonic speech can be carried.

We have not considered the mechanism whereby the electric and magnetic flux, when it reaches the receiving end, is absorbed and its energy utilized for the performance of any kind of work, such as the operation of a motor, the production of signals, or of articulate speech. It has been sufficient to point out that the electric current runs through the insulator from one end of the circuit to the other, and is guided by the two conductors, which with the insulator form the circuit. If it were not for these two conductors, any electric wave or impulse would radiate out into space in all directions, like light from an unprotected candle. The wires do for the electric wave what a reflector does for the search light; namely, localizes and concentrates the beam into a single path, whereby it may be transmitted to the desired point with the minimum attendant loss in transmission.

Discussion.

Mr. Paul A. N. Winand said:

I have been very kindly invited by the authors of the paper to participate in its discussion. I wish to express first my appreciation of the remarkably thorough, clear and original manner in which

they have accounted for the conditions which exist *in the space surrounding the conductor* in the phenomenon called electric current. In fact I could not attempt to add anything to this very clear exposition. I have therefore collected the objections that can be raised against some of the views and conclusions of the authors.

We first encounter a difficulty as long as we do not bear in mind the dual nature of the electric flux considered in relation to electrostatic conditions. The flux is to be taken, respecting one of its manifestations, as a measure of electric quantity inasmuch as, when rushing, each unit will produce the same magnetic flux, but this effect is independent of the difference of electric potential. The energy transferred is, however, proportional to this difference.

In the case represented by Fig. 39 of a perfectly insulated closed circuit, the quantity of flux, owing to the perfect insulation, must remain unchanged as it rushes along the line, but the other factor in the transfer of energy, due to the rush of flux, the difference of potential, decreases as the energy is transformed into heat in the conductor. If I understand the authors correctly, they consider the process as entailing a diminution of the first factor (quantity) by partial reflexions constituting the imperfect conduction, while the second factor remains unaltered. It is difficult to see how, with perfect insulation, at any point of the line, where such reflexions occur (the reflected fractions of flux returning towards the origin), energy will cease to be electric and become thermic, since the reflected fractions will carry their energy away undiminished from that point, while the unreflected part of the flux will carry its share away in the primary direction of main rush.

As to the view held by the authors that the electric current runs through the insulator, or, more broadly, through the space outside the conductor, and is merely guided or localized by the latter, it seems to me open to some grave objections. It is true that the old view, which considered the conductor as the only real seat of the phenomenon, is not tenable. But there is another intermediate position, which has been expounded by Poynting, Lodge, J. J. Thomson and others, which is: that while the current flows through the conductor, the energy, which is generally transferred simultaneously, travels through the space surrounding the conductor.

As stated by Lodge: "We must learn then to distinguish between the flow of electricity and the flow of electric energy; they do not occur along the same paths. . . . . Electric energy is not

to be regarded as pumped in at one end of a conducting wire and as exuding in equal quantities at the other. The electricity does indeed travel thus, whatever the travel of electricity may ultimately be found to mean, but the energy does not." Poynting expresses it thus: "Formerly a current was regarded as something traveling along a conductor. But the existence of induced currents and of electromagnetic action at a distance from a primary circuit, from which they draw their energy, has led us, under the guidance of Faraday and Maxwell, to look upon the medium surrounding the conductor as playing a very important part in the development of the phenomena."

I am not prepared to abandon this intermediate point of view for the reasons which I shall presently state. It naturally depends to a great extent on what we are to understand by an electric current. The nature of electricity being unknown, this phenomenon can only be dealt with as a sum of correlated effects. Some of these occur in the conductor, some in the space outside of it.

One fundamental relation was obtained when it was proved by experiment that the translatory motion of a charged conductor produced the external effects of a current; the effects otherwise found in the conductor being then absent because the conductor moved with the charge and with its external condition or electric flux.

It might be argued that the conducting body, say a charged sphere, should be considered as being mainly a discontinuity in the surrounding insulating space and that the displacement of this discontinuity created the effects by disturbing the space. The experiments of Rowland, however, have established that a rotary motion of a plane conducting disc around its axis produced the same external effects as a current and in this case the conductor, considered as a discontinuity in the insulating space, did not change its position. Does this not tend to show that the unknown condition which moves bodily with the substance of the conductor in the one case moves along the conductor in the other case, which is called current proper?

On the other hand we find that in the case of current proper, effects are produced within the conductor, and we find also that these effects occur not merely at the boundary between conductor and surrounding space, but throughout the cross-section of the conductor. This is undoubtedly true of the heating, the electrolytic effects, osmotic effects, migration of the ions, actions at the

electrodes, some luminous effects (as in gases), thermo-electric effects broadly and of some magnetic effects. It is an established fact that when a conductor carries a so-called current the magnetic lines of force or flux do not exist only in the space around it, but they are present also within the cross-section of the conductor. Their density is, however, smaller at points inside the cross-section than at points immediately outside of it and at the centre of a circular homogeneous cross-section this density is equal to zero. Does this not clearly point to the conclusion that the action which produces the field in the surrounding space has its seat in the cross section of the conductor and extends throughout the same?

Even for effects such as those of so-called free static electricity which seem clearly to have their seat at the boundary between the conductor and the space surrounding it, can we disregard the conductor which is an essential part of the apparatus, though the effects so far discovered in such cases seem to reside in the surrounding space?

Turning now from the consideration of continuous currents to that of very rapidly alternating or freely alternating currents which generate waves of electromagnetic disturbance in space, as first demonstrated by Hertz, we find that, on connecting the charged conducting bodies, the disturbance originates on these bodies and gradually spreads into space with the velocity of light. The phenomenon starts with a current having its seat on the conducting bodies and the surrounding space is affected subsequently, as by light emanating from a spark. Is it then not natural to consider the conductor as the seat of the current and as the primary factor in the apparatus?

In view of these considerations, I cannot but retain the point of view stated above, though I am ready to admit that, as the changes of distribution of energy take place through the surrounding space, the latter may be considered as more important than the conductor. It should not be forgotten, however, that we can only postulate but not demonstrate the travel of energy, while we can measure its disappearance at one point and its appearance at another. We can only find changes in the distribution of energy. Now if we consider a conducting circuit of inappreciably small resistance; a current of any strength can be existent without a comparatively appreciable change in the distribution of energy, which shows that even the practical importance of this action is not always evident.

PROC. AMER. PHILOS. SOC. XXXVI. 155. M. PRINTED JULY 29, 1897.

DR. A. MACFARLANE: I wish first of all to express my sense of the admirable manner in which the authors have carried out the aim which they set before themselves. Behind their description of the manner in which an electric current is now believed to be transmitted there is a great amount of mathematical analysis and experimental verification.

In a work on the *Applications of Electricity*, written by Count du Moncel before the beginning of the great industrial development of electricity, he refers to a fanciful plan of a M. Charles Bourseul for transmitting speech by electricity. The Count makes great fun of the idea; yet he lived to write a book on the telephone. What struck him as especially absurd was that vibrations produced by the human voice could be thought capable of transmission through a solid wire of copper. And indeed it is wonderful how electricians have been so long content to regard the current of electricity as transmitted by the copper molecules, or even by the ether in the wire between the molecules.

In the study of electrotechnics there is nothing more important than clear ideas about the relation of the electric current to the associated magnetic flux. It is important to observe that there are many analogies between the two; but it is also important to observe that the analogy is not complete. The electric current involves in its idea the element of time in a way that the magnetic flux does not. Now observe how the theory expounded explains this. We have the complementary ideas of electric flux and of magnetic flux and also the other two ideas of rush of electric flux and rush of magnetic flux; the electric current in general meaning motion of the combined flux.

For some time it was customary to neglect the study of static electricity because its connection with current electricity was not evident. But observe that the one idea—electric flux—comes from the old science of static electricity, and the other idea—magnetic flux—from the old science of magnetism: together they explain the phenomena of the flow of electricity along a conductor.

In the text-book of *Electricity and Magnetism* which I studied there was an article headed "Velocity of Electricity." Account was given of some experiments made to determine the time required for the transmission of signals along conducting lines; the disagreement of the values obtained was pointed out, and the writer concluded that properly speaking there was no such thing as the

velocity of electricity. But observe how the theory expounded rests on that very idea, how it explains all the seeming contradictions, and shows what in certain cases reduces the velocity of electricity from that of the velocity of light in the ether.

Stated Meeting, April 2, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, 45 members.

Correspondence was submitted.

Mr. Pettit, on behalf of the Curators, presented a report, recommending that the North Room be fitted up for the use of the Cabinet.

Dr. Pepper presented the report of the Special Committee on the Needs of the Library.

The following resolutions were then adopted:

1. That the immediate needs of the Library demand that the North Room be devoted to its purposes.

2. That the Peale Collection be maintained in the North Room for the present.

3. That the collections of plants be transferred in trust as a deposit, subject to recall, to such institution as may be ordered by the Society.

4. That the duplicate collection of rocks be submitted to a Committee of Geologists (Messrs. Lyman, Prime, Frazer and Platt), to report to the Society their recommendation as to its disposition.

5. That a Special Committee of nine (Dr. Pepper, Messrs. Harris, Pettit, T. H. Bache, Price, Frazer, Stone, Jos. M. Wilson and Hays) be appointed to adopt plans for the adaptation of the North Room for the above purposes and to make suitable provision for the other objects of the Society, and that the Hall Committee be empowered to expend a sum not exceeding one thousand dollars in carrying into effect the plans so adopted.

A letter from Judge Mitchell on behalf of the Commission to collect and print the Statutes at Large of Pennsylvania, from the foundation of the colony to the year 1800, asking that the Society grant it the privilege of using a volume of

MS. copies of laws prior to 1700, in the possession of the Society, was received.

Dr. Hays stated, in connection with Judge Mitchell's letter, that he had a few days ago incidentally called the attention of Dr. Frederick D. Stone to a manuscript volume of laws of the Province of Pennsylvania, passed prior to November, 1700, which had been presented to the Society in 1835, by the late Joshua Francis Fisher, Esq. Dr. Stone at once recognized that the volume might have a very important bearing on the work of the Commission appointed in 1883 by the State of Pennsylvania to examine and collate, and authorized some years later to publish, the complete text of the Statutes at Large of Pennsylvania from the foundation of the Province, 1682 to 1801, of which the second volume (the only one yet issued) has just been presented to the Society by the Commission. The principal reason why the Commissioners had delayed the printing of the first volume was due to the fact that certain laws, twelve in number, noted in the minutes of the Provincial Council as having been passed prior to November, 1700, which date was adopted as the starting-point of the second volume, could not be found. Official inquiries made at Harrisburg, and at the Public Record office in London, elicited replies that no such acts were in the possession of the State or of the English Government. Fruitless search was also made at West Chester, at New Castle and at Dover, as certified copies of the acts, as passed, were then usually sent to the clerks of the several counties. The Penn papers and the early manuscripts in the collection of the Historical Society of Pennsylvania were carefully examined in vain, and the Secretary of the Commission, Mr. Charles R. Hildeburn, personally made a thorough but fruitless search in the Public Record Office in London for these missing laws. Of all this Dr. Stone was fully aware, and he at once suggested that the attention of the Commission be called to the volume shown him.

Mr. Justice Mitchell, the Chairman of the Commission, and Secretary Hildeburn, upon being informed of the exist-

ence of this valuable and important volume in our Library, at once subjected it to careful examination and found that it contained many of the laws passed prior to November, 1700, including the twelve missing ones, viz., one act passed June 9, 1694; two acts passed February 10, 1699–1700; one act passed May 16, 1700, and eight acts passed June 7, 1700. Some in not quite as satisfactory form as could be desired, but most of them duly attested by the Speaker of the Assembly, signed by Governor Fletcher, and the later acts by Governor Markham, and sealed with the "Lesser Seal" of the Province.

It is interesting to note, in this connection, that the use of the "Lesser Seal" for such a purpose was a most extraordinary proceeding, and can bear no other explanation than that it was done by William Penn's orders with a view to his claim to a veto power, which was subsequently denied him by the Crown, as the later acts are all passed under the "Great Seal" of the Province.

The only copies of the laws passed prior to November, 1700, possessed by the State and from which the Commission had intended to print, consist of unattested copies made by Patrick Robinson, Secretary of the Council. Hence the Commissioners now desire to print from the duly attested copies of these laws belonging to this Society, rather than from the unattested copies belonging to the State.

It is surmised that the copies contained in the volume belonging to the Society may have come into the office of Andrew Hamilton during the period when he was Attorney-General of the Province, and were acquired by Mr. Fisher in the course of his examination of the Hamilton papers deposited at "The Woodlands."

The finding of these acts will place the Commonwealth of Pennsylvania in possession of a complete set of its legislative enactments, from the founding of the Province to the readily accessible "Pamphlet Laws" beginning with 1802. All but two of the original thirteen States of the Union have, at one time or another, attempted to make and publish similar collec-

tions, but not one has succeeded in gathering together all its laws, but now, with the use of the volume which Mr. Fisher with intelligent discrimination rescued from oblivion or worse, and which the American Philosophical Society has so carefully preserved, Pennsylvania will be the only American Commonwealth that is able to present to the world an unbroken series of its own laws.

The following resolution was then adopted:

That permission be given to the Commission for the Compilation of the Laws of Pennsylvania prior to 1800, to refer to and to copy, if they so desire, the MS. volume of original laws of Pennsylvania from 1683 to 1700, presented to this Society in 1835, by Joshua Francis Fisher, Esq., under such regulations as the Library Committee may prescribe.

Prof. Robert W. Rogers, of Drew Theological Seminary, Madison, N. J., and Prof. Morris Jastrow were appointed delegates to the Congress of Orientalists to be held at Paris this summer.

The Society was then adjourned by the presiding officer.

Special Meeting, April 23, 1897.

President FRALEY in the Chair.

Present, 20 members.

Dr. Morris read a paper on "The Relation of the Dodecahedron found near Marietta, O., to Shamanism," which was discussed by Mr. Cushing.

Dr. Harrison Allen laid before the Society a chart of Australian rock carvings, by R. H. Matthews.

The Society was then adjourned by the President.

RELATION OF THE PENTAGONAL DODECAHEDRON FOUND NEAR MARIETTA, OHIO, TO SHAMANISM.

BY J. CHESTON MORRIS, M.D.

(*Read April 23, 1897.*)

I regret that I am unable this evening to present to the Society, as I had hoped, a very intelligent and well-educated Néz Percé Indian, Mr. Lewis D. Williams, who called upon me some two months ago and read a paper which he had prepared on the education and training an Indian boy receives in his native home. It recalled vividly to me Dr. Brinton's communication to us two years ago on the Nagual form of worship (*Proc.*, Vol. xxxiii, pp. 4, 11, 73), and I had hoped to secure his presence. Unfortunately I have lost trace of him (as he is no longer in the employ of the Bureau of Am. Ethnology at Washington), and can therefore only give a résumé of it from memory. He left his tribe when about fifteen years old, was educated at Carlisle and the University of Pennsylvania, before entering the employ at Washington of the Bureau of Am. Ethnology. He spoke of the boy's close observation of nature in the world around him and his companions, of the inquiry which arises in all human hearts as to the meaning and object of life, and the forces which are displayed, the means of utilizing them, of obtaining success: of the belief in hidden unseen powers controlling or directing or opposing our efforts: of the brave hunters and successful warriors, of the older wiser rulers, of the medicine men and the ceremonial dances and rites of the tribe. He told of the time when the boy hitherto nameless must take, or have given to him, a name. What shall it be? He told the myth that once on a time a wise medicine man had a sacred tepee; to him came the beings which became the various animals and birds, each with its own ambition. One would come and say, "I want to be an eagle." "Well, let me see how you can fly." Off he soared, and came back after flying up toward the sun, and was received with the encouragement, "All right, go and be an eagle." Another wanted also to be an eagle, but only fluttered a little way, lit upon a tree and came back chattering, to be told, "No, you can't be an eagle, you must be a bluejay." Another showed ability, and was allowed to become, at his desire, a wolf. Yet another, try-

ing to run like him, only ambled around and sat upon his haunches to be told with a laugh, "No, no, you can only be a coyote." (This reminded *me* of the bringing of the animals to Adam for their names.) Filled with longing to know his fate in life, the boy goes off into the forest, and communes with nature. He longs to be something, somebody. He tests his powers of endurance, his skill, his desires. Many and long may be his rambles in this effort to place himself in his proper niche in the world. He becomes dreamy—he longs to see a vision or to have some sign to direct him. Perhaps some night one of these unseen spirit forces may make itself known to him. At last, one night when all alone on the mountain side, he sees, or thinks he sees, a wolf approaching, who comes and talks to him, encourages him, lays open his career of duty to him, and tells him if he will be brave and faithful he will aid him and cause him to triumph over every difficulty, bids him come close to him and pluck some hairs from his neck and keep them always with him so that whenever he is in trouble he can by pressing or rubbing them call his guardian spirit to his aid and thus be enabled to succeed and triumph over his difficulties or enemies, or receive counsel in emergencies. The boy returns home, tells his experiences, is tested, and if found truthful and brave is initiated into the lodge under the guardianship of the wolf which he takes as his totem; and in the sacred dances wears the appropriate symbolic mask. Little by little, year after year, as he shows himself fitted and acquires more knowledge and experience, learns more of the legends of the tribe in which are crystallized the results of their contact with nature and their reasonings upon it, he is advanced more and more, and becomes a medicine man, or an elder, or chief, taking part in the councils and directing the affairs of the community. The older, wiser, more reliable he becomes the more respect is shown him.

The idea, so common among us, that their medicine men are all mere quacks and humbugs, charlatans of a low grade, and that all their dances are low orgies and mere devil-worship—that the Indian is an untutored, untrained savage, bloodthirsty, revengeful and treacherous—is largely erroneous, and due to a lack of proper and adequate knowledge of him as he really is: and of consideration of his circumstances in the world. Place a human being of average capacity of any other race in similar conditions, and the probabilities are that his chances of survival would be less, to say

nothing of the system of a philosophy of the unseen but no less real forces around, above and within him which he has developed. He is in many respects a child—and so we too are but "children of a larger growth." When things hurt or oppose him, or others injure him, he grows angry and avenges himself unreasoningly and excessively, as a child would. Higher aims and purposes he has little chance to acquire. Yet there is the yearning for the higher, the better—for the pure and true, for the brave and good: when these are shown to him he seizes upon them and grows to the full stature of man. How often this has been shown—and yet how often it is ignored!

In every age and clime, among every race, there have been and are those who have sought to know more of the truths around, above and in them—men who have risen above their fellows, and have been looked up to as leaders and advisers of the rest—and also in every race and age these men have been credited with supernatural powers—have been supposed to be in communication with the world of spirits: and too often alas they have used their attainments only for their own selfish ends: have availed themselves of the ignorance and superstition of those beneath or around them and by trickery have magnified their influence. If we, however, think of the meaning of such terms as "soothsayer," "wahrsager," "wise heart" (wizard), "astrologers," "magicians," and think of their succession in the history of our race, from that of the wise men of the East, Balaam, Jannes and Jambres, the Pythian and Delphic oracles, the Roman augurs and haruspices—nay, even of Paracelsus, who may almost be called the father of modern physiological medicine, we shall have less disposition to condemn so utterly the Indian medicine man: especially as we read of Daniel, who was made and seems to have accepted the post of "chief of the magicians, soothsayers, astrologers and Chaldeans." In fact, the yearning after occult science is as powerful and prevalent in Paris, London and Berlin, not to mention among ourselves, as in India among the Brahmins and Buddhists—it is a human yearning. To penetrate the secrets of or to forecast the future—to resort to some species of divination—to seize upon and compel the unknown, is so human that Goethe makes it the aspiration of his Faust.

We need not wonder then that Shamanism, the idealizing and spiritualizing of the forces of Nature, became so prevalent among the children of the forests and mountains, of the plains and sea-

shores, of the New World as it did in the Old; that mystic dances, rites and symbols abound among them—that Nature speaks to them with myriad tongues: that they should try to penetrate her secrets by methods of divination more or less analogous or identical with those of similar races. But here comes in a factor which is too often disregarded—the influence of race. Truth, absolute truth, must always remain the same: not so our appreciation of it, which must in every case be more or less partial, more or less incomplete. Some races have little or no idea of harmony—others of lapse of time—others of liberty—others of home. The Western races of the Old World view things objectively, the Eastern subjectively. The Indian resembles the latter—the world is in him and he is of it. Our Aryan brains take readily the idea of three dimensions in space. To the Indian, and to the Eastern mind, there is another—the fullness. It is hard for us to grasp this—it is not the length and breadth and thickness of a cube for instance, but the whole of it, which is as much to be considered as any one of its sides. A cube would, therefore, be represented numerically by 7: a dodecahedron by 13. Among the Mexicans the thirteen lunar months would thus correspond in the year with the twelve zodiacal signs and the earth which passed under and embraced them all. Again, the five digits on each hand came to be a measure of a man's power or individuality, and thus a sacred number. It would then require but little stretch of imagination to suppose that a pentagonal dodecahedron, were such a form known to them, inscribed with zodiacal characters, might be the emblem of the world: and the best time for the activity of a man in some pursuit in which he might wish to engage might be shown by the zodiacal sign which came uppermost when the dodecahedron was thrown or rolled with appropriate ceremonies.

Such is the hypothesis which I would offer as to the character and uses of this curious stone dodecahedron, which was sent to the Society on October 19, 1792, and has since been lying in the Cabinet. The record shows it to have been taken from a bluff on the Ohio river, about thirty miles above Marietta; and it was sent here with other Indian relics. The edges show slightly conchoidal fracture: the sides are finely polished, showing also indistinctly drawings of figures upon them which have been made, Mr. Cushing thinks, with stone tools: it is black, of moderate hardness, sp. grav. about 2.78, and effervesces with dilute acid.

In Vol. xxi, Pls. i, ii and iii, of the *Proceedings*, some drawings are given of the Pictured Rocks on the Monongahela, showing good examples of the Shamanistic symbol writing of the tribes which roamed there before the advent of the white man, and I have the pleasure also of exhibiting casts made from impressions in plaster taken from some rocks in the Susquehanna at Safe Harbor, Lancaster county, Pa., and presented through Prof. T. C. Porter, by the Linnæan Society of Lancaster county, figured in the *Proc.*, Vol. x, pp. 30, 255, and Pls. i and xiii. These figures, cut by stone implements in the limestone rock, give striking representations of the sacred dances participated in by Indians wearing masks, and of various mythic creatures such as the thunder-bird, etc.

The 12 faces of the figure may be divided into 4 groups of 3 faces each, forming 4 solid angles, which may be connected so as to form the four-legged Sphastica: or those may be united to form a triskele. There are in all 30 dividing edges and $12 \times 30 = 360$; add a 5 and you have the days of the year. The 13 (sum of the faces and the object itself) multiplied by the 4 points above noted gives the number 52, the Aztec cycle—while 4 adjacent faces, each with 5 sides, would give 20, the unit of a man. Or, again, 3 edges unite so as to form 20 three-sided points. Thus the cube and pentagonal dodecahedron might be used to represent all the mystic numbers. While those of the cube were connected more with the extreme orient, those of the dodecahedron may be found there as also in Egypt and Mexico.

I cannot refrain from the suggestion that perhaps this dodecahedron may throw some light on the customs and civilization of the mound builders of Ohio.

Discussion.

Mr. Frank Hamilton Cushing, in response to a request of the President, commented upon and discussed the subject at considerable length.

After a few general remarks relative to Shamanism, or, more properly, Primitive Priestcraft, which he defined as the outgrowth of the "Religion and Philosophy of Mystery," of the attempted explanation of the unknown,—the realm of which, he stated, grew greater and greater as we progressed farther and farther backward

in time and the history of human culture growth,—he expressed himself as follows:

The account Dr. Morris has given us as to what Mr. Williams related to him concerning the life of an Indian youth of the Nez Percé tribe has interested me exceedingly by reason of its striking similarity to what I have myself heard, seen, and experienced among the Zuñi Pueblo Indians of New Mexico.

With these people, a child is not thought of, when first born, as quite yet a living *mortal* being. It is referred to as "it" or the "new being," nor is any name given to it until after the lapse of nine days. It is supposed to be *kái'-yu-na* and *ai'-ya-vwi*—unripe and tender, or soft and susceptible as are germinating seeds or unfinished clay vessels, until after one full day for each of the lunar months of its inter-uterine gestation has passed. During this period of nine days it is usually kept with its mother, secluded from the outer world and from sunlight, in order that it may gradually become hardened to, and so, safe in the "world of daylight"—as these people term the scene and condition of mortal life—that is, condensed to "middle being"—as they further term man's particular mortal existence.

At the close of this ceremonial period the umbilical cord, which has meanwhile sloughed off or has been removed and zealously cared for, is ceremoniously buried in the soil at some particular place, in order that thereat may be formed the "midmost shrine" of the child, and therein its connection with the earth mother—as formerly with its mortal mother—may be established, and that its vitality apart from her thenceforward, be maintained—by thus placing within the fertile bosom of the Universal Mother, that through which erstwhile the child received separately, or secondarily, its being nourishment and growth, from its human mother.

Passing over many other ceremonials which attend the first naming of the child, its introduction to the Sun and to the tribe of its descent, on the early morning of the tenth day,—that is, at the end of these nine natal days,—a few words relative to the meaning of the "midmost shrine" will serve to indicate what would likely be the symbolic significance to a people like the Nez Percé and the Zuñi Indians, of such an object (whether natural or artificial) as the one to which Dr. Morris has called our attention.

He has quite accurately stated, in the theory he has advanced regarding this object, the view one of these Indians would hold, as

to the meaning of the *number* of its sides or faces and itself. To one of them, a cube would not be representative of six, its number of superfices, but of *seven;* and a dodecahedron, not of twelve, but of *thirteen*. For, when an untutored or primitive man like him, contemplates or considers himself or any other distinct thing, in his or its relation to space or the surrounding directions, he notes that there is ever a front or face, a rear or back; two sides, or a right and a left; a head and a foot, or an above and a below; and that of and within all these, is himself or it; that the essence of all these aspects in anything, is the thing-itself—that is, the thing that contains their numbers or sum, yet is one by itself.

This is indeed the very key to his conception of himself and of everything, in relation to space and the universe or cosmos. He observes that there are as many regions in the world as there are aspects of himself or sides to any equally separate thing; that there are as many directions from him or his place in the world (which is his "midmost" or place of attachment to the Earth-mother) or from anything in the world (which is *its* midmost or natural station) toward these corresponding regions. Hence to him a plane would be symbolized not by four, but by *five*, its four sides and directions thence, and its central self—as was actually the notion of the Prairie tribes; a cube, not by six, but by seven, as was the notion of the Valley-Pueblos and Navahos; a dodecahedron, not by twelve, but by thirteen, as was the notion of the Zuñis, the Aztecs, the Mayas, and apparently—from this example—of the Mound builders as well.

With all that I have thus far said I cannot yet have made clear to you the relation this supposed connection of beings and things to their surroundings, to the regions in front, behind, at the right and left sides, and above, below and within them, can have to the subject under discussion. It will therefore be necessary for me to crave your patience while I enter a little more fully into a consideration of the beliefs of primitive man concerning *force*, *life*, and *form*, for it will be seen that these beliefs have a direct bearing on this apparently fantastic and mystic meaning of the numbers *seven* and *thirteen*.

To the primitive Shaman, all force necessarily seems to be derived from some kind of life, since he continually sees force as motion or stress originated in, or initiated as action by, life in some form—his own, or some other. Now the supreme characteristic or

concomitant of his own or of any other form of life, is breath, which like force or stress, is invisible; hence he reasons that force is breath, and conversely that breath is the force of life. He sees that this breath enters into and issues from every living being, and since every such being has distinctive form, he further reasons that every separate form, whether animate in our sense or not, has life of some kind or degree. He has, for example, no knowledge of air—as a gas—no knowledge of it other than as wind, and no conception of wind other than as breath, as the sort of something that he feels when he blows upon his hand and knows absolutely that he or his own breath is blowing, and that this breath it is that is coexistent with his mortal existence.

Therefore, he thinks not only of all forms as living, but also of the wind as necessarily the breath of some living form or being. And since his own little breath is so intimately of himself, he naturally imagines that this other greater breath must needs be as intimately that of some other and correspondingly greater and more powerful—what though invisible—being. He also imagines that this great being of the wind resides in the direction whence comes prevailingly its wind or its breath. Now when he observes that there are prevailing or distinctive winds of the diverse directions,—that of the north which blows hardest of them all and chiefly in winter; that of the west which blows more temperately and chiefly in spring time; that of the south, which blows softly and most frequently in summer; that of the east, which is again more fierce and chilly, and blows mostly in autumn; he not only severally locates these winds in their various quarters, but also differentiates them, and believes that the wind-being of the north produces cold and winter; of the west, moisture and spring; of the south, warmth, dryness and summer; of the east, coolness again, frost, and therewith the aging or maturing of all growing things, and autumn. And so to him the element of the north world is wind (or air, breath) preëminently; of the west world, water; of the south world, fire; and of the east world, earth or its seeds; and that each of these elements is produced by or is under the dominion of the special wind-god of its quarter; yet all combine, in the regular succession of the seasons, to make this World of the Middle what it is from year to year.

Now we shall see how this kind of belief comes to affect very directly the organizations, institutions and ceremonials (Shamanistic in particular) of primitive man, by examining into his mode of

personifying the various gods or wind-monsters of the several quarters, and then of relating them to various divisions of his tribal communities. We have seen how he imagines that each one of these great world-breaths—productive as they are of effects so different—must proceed from beings of equally different character. How, therefore, he first not only locates these monster beings definitely in the several quarters of the world whence the winds or their breaths blow, but how also he imagines them to be beneficent or evil according to the various effects of their breaths, and then endows them with personalities corresponding to those of such of the animals especially characteristic of these several regions, as by their actions seem most closely to conform to these effects. The connection this has with the sociologic organization of the tribe may be explained without entering greatly into detail relative to the constitution of Indian society. You are all aware that the sociologic institutions of primitive peoples are almost universally Matriarchal, that is, are based upon *Clan* organization and mother descent. With them, each clan in the body politic is symbolized by some totem, animal or plant. Now since the various animals are supposed, according to their kinds, to be especially resident in one region or another, not only is there attributed to the Great Being or God of Wind in a particular region, a form more or less like to that of his supposed kind of animal therein, but also, the clans are organized with reference, in turn, to the supposed relation of their totems to these various animals and animistic or mythic beings of the special regions. And so, when, for example, a name is to be conferred upon a child of one of these totems, some process of divination must be entered into to determine what shall be his relation to the creatures and the deific being of one region or another, and correspondingly, of course, to his fellows among the clans. For it is held to be essential that this sacred relationship be symbolized, in some way or another, in the choice of his totemic name, and thus—as well as for many reasons into a consideration of which I cannot enter here—must be divined. Now in this process of divination, various instrumentalities are employed. For example, among the Zuñis, wands painted in diverse colors—each color being symbolic of a special region and plumed with appropriate bird feathers,—are sometimes set up in balls of clay, each placed out on the floor in the direction of the region to which the color of its wand relates it. Then it is noted which of the plumes waves most

actively in any wind (or breath) that may be stirring. From this, the spiritual relation, so to say, or the source or totemic origin of the child is divined, and he will be named, and to a certain extent the course of his life will be determined upon according to this divination. For example, the Zuñi totem gods of the several regions are: the Gray Wolf for the East or Dawn-Land; the Mountain Lion or Puma for the North or fierce Winter-Land; the Black Bear for the Land of the West or Night; the sun-loving Badger for the South or Summer-Land; the Eagle for the Sky and Light, and the Burrowing Mole for the Under-Land and Darkness. Let us suppose that the plume on the white wand—the one that is set up toward the east—waves most actively; then, what though the child belong to a clan or totem of one of the other regions, he will nevertheless be regarded as *spiritually* related to the Gray Wolf of Dawn, and it will be believed by his fellows—and with their belief he will himself become, as he grows toward puberty, more and more impressed,—that he is destined for membership in the sacred organization or Shamanistic Society or Lodge of the Medicine-men of the East, or of the Wolf deity. Now when the age of puberty is attained, and the boy is to be solemnly invested with the garment or clout and the responsibilities of manhood, he is, as in the account quoted by Dr. Morris from Mr. Williams, required to pass through various ordeals, such as a period of vigorous fasting and purification (this both by means of emetics and purgatives); and to retire to some lonely spot and there keep, day and night, lengthy vigils, whereby it is sought to diminish for a time his earthly grossness interests and affections, to "still his heart" and quicken his spiritual perception and hearing of the meaning of the "Silent Surpassing Ones." This is in order that he may gain sign from or actually behold one of the Beings who wield, in the great quarters, the forces of nature, and who shall thereafter be his special Tamanawa or spiritual guide. It is also in order to aid him in seeking for some objective sign by which this relationship to his Genius may be proven to himself and made manifest to his people. In a condition of exaltation as he is—and I can attest to its absorbing nature, through having myself endured such an ordeal—you can well understand that his perceptions will become startlingly manifest in the various visions and signs he sees. These will seem to him, I can again personally assure you, far more real than the most absolutely actual things he has ever beheld or experienced. Perchance he

gazes at the mist, or a cloud in the sky. The cloud will surely seem to take the form of a great gray wolf, and when he seeks for some token of that God of the Sky,—a tooth-like fossil, a few hairs maybe, which he may find on the ground nearby or underneath the apparition, will be reverently accepted as potent amulets, and he will bear them to the tribal Fathers or Shamans, and by them they will be received as a sign of his Genius, and he will be relegated to the phratral division or lodge of the Wolf. Or again, it may be that he will find a crystal, and because this crystal shines clearly and therein resembles the light by which we see and the eye through which we see—and hence is regarded as helpful in seeing—it will be regarded as a token of seership, as a sign of the Seeing Spirit, and fortunate the youth who is thus supposed to be endowed with the power of penetration into the unseen. To give yet one more example, let us suppose that he finds a concretion exhibiting spiral or concentric lines. He will regard this as a symbol of the Midmost itself, a token of his relation thereto also—no matter to what totem he may belong, or to what region he may be related by birth. For the spiral lines perceived in this crystal resemble those of the marks upon the sand produced by the whirling about of objects like red-topped grass by the whirlwind, yet which are regarded as the tracks of the whirlwind god, whose breath is the midmost of all the winds of the world.

Permit me to here give parenthetically a striking illustration of the way in which these primitive Shamans personify phenomena of nature, by instancing their personification of this god of the whirlwind. Of all the winds of heaven, the whirlwind alone is upright—progresses as man does, by *walking* over the plains. The whirlwind god is therefore endowed in part, with the personality of a man; but like the eagle, also, the whirlwind flies aloft and circles widely in the sky; therefore he is endowed with the wings and tail, the head, beak and talons of an eagle. Since the sand which he, the whirlwind, casts about, pricks the face as would minute arrows, the dreadful wings of the god are supposed to be flinty, and his character warlike or destructive, as is that of the eagle; yet of all the Beings of Wind, he is the most potent, for he twists about or banishes utterly from his trail, either the north wind or the south, the east wind or the west, and overcomes even gravity,—the pulling-breath of the earth or under world,—and therefore is the god of the midmost among all the six gods of wind. Thus, lucky in a purely prac-

tical way, is he who finds under given auspicious circumstances, his name-token in the shape of a little concentric concretion, for he will be in the line of ordination thereby, to the Central Council or Priesthood of his people.

And now I would fain add a word, another parenthetic statement, in amplification of what Dr. Morris has said in regard to the "Medicine-men," Priests or Shamans, of such primitive peoples,—in regard, that is, to their earnest character, to which I can fully testify.

I am aware that they are generally supposed to be mere quacks, charlatans or jugglers. I never knew one of them to be anything of the sort. Quite the contrary. I have lived among them in the tribe of my adoption, and was even initiated as one of their number, so far as was possible for one not born in the tribe, namely, into their Society of Warriors—"the *A'pithla Shi'wani*," or "Priesthood of the Bow"—and, moreover, I have been received in fraternal manner, by members of the priesthoods or medicine societies of other tribes. Now hardly a traveler among the Indians who does not come back and report what he thinks he saw when watching the operation of one of these medicine-men, but almost invariably his report is unreliable, from lack of understanding of what he saw. Let us take, for instance, the common account that is given of an Indian Medicine-Man endeavoring to effect a cure. It is said that he pretends to charm or to suck or rub forth a worm or a wasp or a grub or some other small object, from the diseased part of the man or woman he is treating. The traveler usually states that he saw the Medicine-Man, after going through his ceremonies, pretend to pluck out a wasp or grub or other object, and hold it up for the edification of the bystanders. A little thought in regard to what really occurs will explain all this. We all have our medical theories; so has the Indian Medicine-Man. Among the injuries the Indians are exposed to by their mode of living, a bruise from a stone or a hatchet would be, let us say, the most frequent. This bruise may fester and give rise to suppuration. The wound, naturally ill-cared for in their condition of life, would readily become offensive and breed maggots, which would batten on the sore. Now these people observe that decaying meat also produces maggots or "turns" to them, for, from their observation of countless slain animals, they believe that all flesh comes from, and returns to, worms. That the flesh may not be further destroyed, the Indian Medicine-Man will seek to exterminate these destructive worms; will seek for some other maggot

which he will squeeze out in order that its form may so be fitted to absorb the invisible form of the infesting maggot; or else he will seek for some insect which preys upon maggots, like certain wasps, and will apply it to the infected place, using such aids as he can, by rubbing, scarifying, squeezing, sucking or blowing the diseased place, until he succeeds in forcing out the pus or black blood or serum and securing or snaring, as he supposes, the seed or occult creature of the ill. Then he will hold up the crushed grub or wasp, merely to show how successfully it has absorbed or fought and destroyed this disease-causing worm, but with no more thought whatsoever of chicanery, than a surgeon among ourselves would have in exhibiting a needle he had extracted from the hand or foot of his patient.

Now I have gone a long way around the subject in hand, in order to measurably substantiate my reasons for thinking that Dr. Morris is correct in his hypothesis as to the sacred and symbolic character and origin of the pentagonal dodecahedron which he has exhibited and commented upon here to-night. A figure even as elaborate and difficult of production in stone as is this, could readily have been formed by Indian artisans. Its shape might have been suggested in the process, perfectly familiar to them, of knapping a block or cube of stone, and afterwards breaking away its angles by battering, to form a sphere; or, better still, by the shapes of balls of clay—naturally formed round in the hands—and used as by the Zuñis in their processes of name—divination just described; or again, by the shapes of pentagonal or other like—ever sacred—crystals. The scratchings or figures observed upon the various faces of this stone are quite such as might well have been drawn to differentiate them as being related to one region or another, and in all probability the figures thus scratched were further marked with pigments symbolic of the different regions, when this stone was used in such processes of divination. Close observation of the more distinct lines of these figures on the faces of the stone, shows that they were made by a flint point, not a metal instrument; for they are double,—that is within each one is a minute bead such as would be produced by the fracturing of a fine point of flint or other hard concoidal stone when drawn over the surface of another stone like this,—and not simply V-shaped as would have been the case had a metal instrument been used.

Some question may arise in the minds of those who have listened to Dr. Morris' paper, and to my comments thereon, as to the mean-

ing of the twelve faces in this particular specimen; since, as I have explained there are only *six* regions, the north, west, south, east, upper and lower, that the midmost is at once surrounded by and contains within, itself. But I failed to say earlier and in the proper connection, that to the primitive-minded man, as there is no form without life, so there is no life-form, without due duality of origin —the father and the mother. Consequently we find that in relation to all things, (with tribes of primitive peoples like the Zuñis of to-day, and like the mound builders of long ago, who possessed and reverenced this object), the sexenary division is duplicated; but since there can be only one middle or content, the sexenary division is with them symbolized by the number seven, and when duplicated, we have, not fourteen, but thirteen; that is, six pairs which are visible, but only one for the concentric or synthetic middle, since there can be but one actual centre or middle to anything, even to the great world.

[Mr. Cushing stated, when a fuller revision of these notes was requested, that he would, at some future time, if the Society so desired, present instead a more comprehensive address on Shamanism in general.]

Stated Meeting, May 7, 1897.

The President, Mr. FRALEY, in the Chair, assisted by Vice-President, Dr. PEPPER.

Present, 68 members and about 100 visitors.

The Secretary presented the following correspondence:

A letter from Prof. James Glaisher, dated South Croydon, March 16, 1897, accepting membership.

A letter from the President announcing the appointment of the following members to prepare obituary notices of deceased members, viz.:

Dr. J. Cheston Morris, for Dr. Henry Hartshorne and Prof. H. D. Gregory.

Prof. Albert H. Smyth, for Prof. George Stuart.

Mr. Joseph C. Fraley, for Mr. Arthur Biddle.

Letters from Dr. J. Cheston Morris and Mr. Joseph C. Fraley, accepting their appointment as above.

A letter from Mr. Franklin Platt, resigning from the Special Committee of Geologists appointed April 2 to report on the rock specimens in the possession of the Society.

Dr. Pepper, on behalf of a number of members of the Society, presented an oil portrait of the late Prof. E. D. Cope.

On motion of Mr. Joseph C. Fraley, the gift was accepted and the thanks of the Society were given to the donors.

The Committee on the Phillips Prize Essay Fund reported the accompanying circular letter, announcing the proposed award of a prize.

PHILADELPHIA, 104 SOUTH FIFTH STREET, April 5, 1897.

The American Philosophical Society held at Philadelphia for Promoting Useful Knowledge has the honor to announce that an award of the Henry M. Phillips Prize will be made during the year 1899; essays for the same to be in the possession of the Society before the first day of May, 1899. The subject upon which essays are to be furnished by competitors is:

"*The development of the law, as illustrated by the decisions relating to the police power of the State.*"

The essay shall not contain more than one hundred thousand words, excluding notes. Such notes, if any, should be kept separate as an Appendix.

The Prize for the crowned essay will be two thousand dollars lawful gold coin of the United States, to be paid as soon as may be after the award. The Society invites attention to the regulations governing said prize, which accompany this circular.

WILLIAM V. MCKEAN,
CRAIG BIDDLE,
MAYER SULZBERGER,
C. STUART PATTERSON,
JOSEPH C. FRALEY,
AND
FREDERICK FRALEY, *President of the Society,*
J. SERGEANT PRICE, *Treasurer of the Society,*
Ex-officiis,

Committee on the Henry M. Phillips Prize Essay Fund.

The essays must be sent, addressed to Frederick Fraley, President of the American Philosophical Society, No. 104 South Fifth street, Philadelphia.

THE HENRY M. PHILLIPS PRIZE ESSAY FUND.

Miss Emily Phillips, of Philadelphia, a sister of the Hon. Henry M. Phillips, deceased, presented to the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge the sum of five thousand dollars for the establishment and endowment of a Prize Fund, in memory of her deceased brother, who was an honored member of the Society. The Society accepted the gift and agreed to make suitable rules and regulations to carry out the wishes of the donor, and to discharge the duties confided to it. In furtherance whereof, among other rules and regulations adopted by the Society, are the following:

Competitors for the prize shall affix to their essays some motto or name (not the proper name of the author, however), and when the essay is forwarded to the Society it shall be accompanied by a sealed envelope, containing within, the proper name of the author, and, on the outside thereof, the motto or name adopted for the essay.

At a stated meeting of the Society, in pursuance of the advertisement, all essays received up to that time shall be referred to a Committee of Judges, to consist of five persons, who shall be selected by the Society from nomination of ten persons made by the Standing Committee on the Henry M. Phillips Prize Essay Fund.

Essays may be written in English, French, German, Dutch, Italian, Spanish or Latin; but, if in any language except English, must be accompanied by an English translation of the same.

No treatise or essay shall be entitled to compete for the prize that has been already published or printed, or for which the author has received already any prize, profit, or honor, of any nature whatsoever.

All essays must be *clearly* and *legibly* written or printed on one side of the paper only.

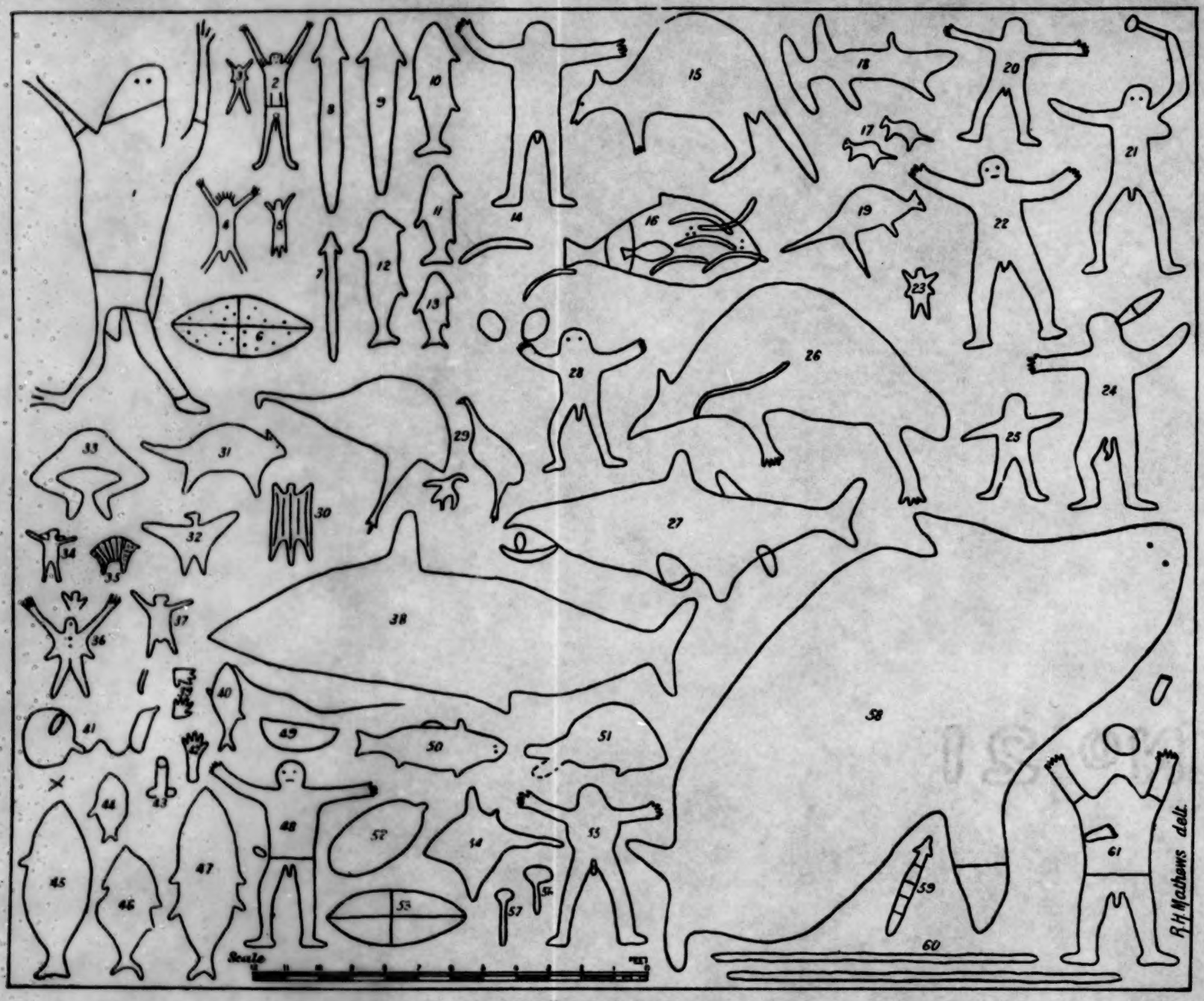
The literary property of such essays shall be in their authors, subject to the right of the Society to publish the crowned essay in its *Transactions* or *Proceedings*.

The Special Committee on Rock Specimens presented a report, recommending that all the specimens which have no labels, or designations by which they can be recognized, and which are not of value for other special reasons, be thrown away. Also that all specimens which can be recognized as to their locality, and are of any scientific value, be deposited in the collection of some institution, subject to recall, and a receipt taken therefor. The report was accepted, and the recommendation adopted.

Announcement was made of the decease of the following members:

Prof. Edson S. Bastin, on April 6, 1897, æt. 53.

Rock Carvings.



Australian Rock Carvings.

Prof. Edward D. Cope, at Philadelphia, on April 12, 1897, æt. 56.

Dr. Traill Green, at Easton, Pa., on April 29, 1897, æt. 83.

Mr. George W. Biddle, at Philadelphia, on April 29, 1897, æt. 79.

The President was requested to appoint members to prepare biographical notices of Prof. Cope and Mr. Biddle.

The following papers were presented:

"Australian Rock Carvings," by R. H. Mathews.

"On the Transitive Substitution Groups that are simply Isomorphic to the Symmetric or the Alternating Group of Degree Six," by G. A. Miller, Ph.D.

Dr. Hays moved that after the presentation of Sir Archibald Geikie's communication, the meeting adjourn to reconvene on Thursday evening, May 13, at 8 o'clock. Adopted.

Sir Archibald Geikie then presented a verbal communication on "Recent Geological Work in the Hebrides and Faroe Isles," for which the best thanks of the Society were voted to him.

The meeting was then adjourned by the President, pursuant to the resolution previously adopted.

AUSTRALIAN ROCK CARVINGS.

(Plate IV.)

BY R. H. MATHEWS, L.S.

(*Read May 7, 1897.*)

At a meeting of the Royal Society of New South Wales, held on the 1st of August, 1894, I read a paper on "The Aboriginal Rock Carvings and Paintings" in that colony, for which I was awarded the Society's medal.[1] I also contributed papers on the same subject to the Anthropological Institute of Great Britain,[2] the Royal Society

[1] *Jour. Roy. Soc. N. S. Wales*, xxviii, 329, 330.

[2] *Jour. Anthrop. Inst.*, London, xxv, 145, 163.

of Victoria,[1] the Royal Geographical Society of Australia[2] and other learned bodies. Since then I have continued my researches, and have succeeded in discovering several other groups of native carvings not hitherto recorded, a description of which I have thought are worthy of being recorded.

In the papers above referred to I have described the way in which these carvings were executed by the native artists, their geographic range, etc., so that it will not be necessary in the following pages to again refer to these parts of the subject. The accompanying plate shows much the largest and most varied as well as the most valuable collection of rock carvings hitherto published. All the figures are drawn to scale from careful measurements and sketches taken by myself, and the position of each on the Government maps is also stated in the descriptions, so that they can readily be found by persons desirous of visiting them. As all the carvings are situated within New South Wales, it will not be necessary to add the name of the colony in the description of each figure.

Plate IV. Rock Carvings.

Fig. 1. This huge, roughly drawn figure of a man is carved on a table of Hawkesbury sandstone, almost level with the surface of the ground, on the old road from Peat's Ferry to Sydney, and is about half a mile northerly from Vize Trigonometrical Station, Parish of Cowan. The old dray track, now little used, passes over this figure, which has caused some of the lines to become rather indistinct.

From the feet to the top of the head measures ten feet eight inches.[3] Both eyes are shown and a diagonal line across the face. There is a line across the body at the waist, across each arm near the shoulder, across the left thigh, and the left ankle. An unfinished line rises from the left thigh, outside of the figure. The right hand and part of the left shoulder have been obliterated by the traffic along the road referred to.

Figs. 2, 3, 4 and 5. This group of carvings appears on a flat

[1] *Proc. Roy. Soc. Victoria*, vii (N. S.), 143, 156.

[2] *Proc. Roy. Geog. Soc. Aust.* (Q.), x, 46–70; *ibid*, xi, 86–105.

[3] For other gigantic carvings of men, the reader is referred to the following plates in various papers written by me on this subject: Figs. 1 and 6, Pl. 16, *Jour. Anthrop Inst.*, London, xxv, 145–163; Fig. 5, Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, xi, 86–105; and Fig. 7, Pl. 9, *Proc. Roy. Soc. Victoria*, vii (N. S.), 143–156.

sandstone rock, about a quarter of a mile in a northwesterly direction from Taber Trigonometrical Station, Parish of Broken Bay.

There are a man and a woman in the attitude of aboriginal dancers; the man is about four feet six inches high from his feet to his hands. The head contains eyes and mouth, but no nose, and there is a belt around the waist consisting of one incised line. On the upper side of the belt, and projecting from it, are two incised lines extending upwards about five inches. Lines are also cut across the arms above the shoulder, with short lines similar to those projecting from the belt extending a few inches along the centre of each arm. The hands have four fingers and the feet four toes each. The penis is shown in this figure by a single incised line,[1] instead of in the way usually found in native carvings.

On the right of the man is a female figure, much smaller, without eyes or mouth. The mammæ are depicted in the manner usually employed by the Australian aborigines in their paintings or carvings of women.[2]

Another carving, Fig. 4 in this group, represents a male figure, which is interesting on account of the lines rising from the head, which may represent hair, or may perhaps be intended for feathers or other ornaments stuck in the hair. The hands have four fingers only, and the feet have been carried away by the weathering of the rock.

On the same rock is another of those grotesque forms, Fig. 5, which are hard to definitely identify, and may be intended either for some kind of lizard or for a human being.

Fig. 6. The large sandstone rock containing this carving is distant from Taber Trigonometrical Station about fifteen chains in a westerly direction, Parish of Broken Bay. It is on the top of the range dividing Smith Creek from Coal and Candle Creek.

This shield is four feet five inches long by two feet broad, and has a longitudinal and a transverse subdivision. In the upper right-hand quarter are four jagged holes cut in the rock, and five similar holes in the lower right-hand quarter. The upper left-hand quarter of the shield contains five similar holes and the lower left-hand quarter six,

[1] Compare with Fig. 4, Pl. 2, of my paper on "Australian Rock Pictures," contributed to the Anthropological Society of Washington, and published in *The American Anthropologist*, viii, pp. 268–278.

[2] For an interesting carving of a woman dancing, see Fig. 3, Pl. 2, *American Anthropologist*, Vol. viii, pp. 268–278.

or twenty holes altogether. These holes are not in any symmetrical design, but appear scattered irregularly over the surface of the shield, and have probably been intended for ornamentation. The ethnological collection of the Australian Museum in Sydney contains a hielaman, or shield, from Queensland which has a longitudinal line and two median horizontal lines, and is ornamented with a groundwork of red dots. On the other hand, these marks may be intended to represent the indentations made by spears.

Near this shield is a hollow, or "pot-hole," in which water collects in wet weather. Around the margin of this small pool of water are a large number of grooves or hollows worn by the aborigines in sharpening their stone tomahawks. For illustrations and descriptions of similar grinding places, see my paper on "Some Stone Implements Used by the Aborigines of New South Wales," *Jour. Roy. Soc. N. S. Wales*, xxvii, pp. 301–305, Plate 43, Fig. 3.

Figs. 7–13. These carvings are all on the same flat rock, situated within Portion No. 1140, of forty acres, in the Parish of Manly Cove. The first three are apparently intended for eels, varying in length from four feet three inches to six feet one inch. Figs. 11 to 13 are all of the same kind of fish, but of different sizes. I am unable to say definitely what fish is intended to be represented, but it has been suggested perhaps that they are grupers. The length of the smallest is two feet four inches, and that of the largest four feet two inches.

Fig. 14. This drawing, which is on the same rock as Fig. 26, represents a man about five feet eight inches high, with a boomerang lying near him. The left hand has four fingers and the right five. The distance from the right toe to the centre of the boomerang is one foot two inches, the length of the latter being two feet four inches. The end of one of the weapons shown in Fig. 60 almost touches the right foot.

Fig. 15. This well-executed figure of a buck kangaroo is carved on a large flat rock of Hawkesbury sandstone, near the southern boundary of Portion No. 717 in the Parish of Manly Cove. The drawing appears to have been intended to represent the animal bent down in the attitude of grazing. The eye, one of the ears and the mouth are shown, the latter being open, which is unusual.

Figs. 16 and 17. These carvings are found on the perpendicular face of a large standstone rock about five yards from the left shore of Cowan Creek, about seven or eight chains above its confluence

with Cockle Creek, in the Parish of Gordon. Fig. 16 represents a fish five feet nine inches long and about two feet nine inches across the body at the widest part. This fish has two eyes and three small dots about two feet three inches from the point of the nose, which are perhaps intended to represent gills. The tail is divided by two curved lines extending from the back to the belly. Within the outline of the larger fish there is a small one about eighteen inches long by eight and a half inches across the body. There are six representations of boomerangs, the most I have yet observed in so small a space, three of them being within the outline of the large fish, two partly within and one outside of the said outline.[1]

Ten feet five inches farther to the right from the nose of the large fish, on the vertical face of the same rock, are two small animals, Fig. 17, which are probably intended to represent kangaroo rats, judging by their size and general aspect.[2] They are each about one foot four inches in length, and are fairly well executed.

The side of the rock on which the figures are cut faces northeasterly, or towards Cowan Creek. These carvings are somewhat uncommon on account of being executed on the face of a vertical rock, such drawings being generally found on horizontal surfaces; they are, however, sometimes met with on rocks occupying different slopes between the two positions mentioned.

Fig. 18. This curious drawing is on the same flat rock as Fig. 26, and is probably intended to represent a fish, real or imaginary.[3] It is five feet three inches in length.

Fig. 19. This figure of a wallaby is on the eastern continuation of the same rock as Fig. 26, but is on the Government road separating Portions Nos. 1139 and 1140 before referred to. The length of the wallaby from the tip of the nose to the end of the tail is four feet five inches; it is in the attitude of jumping, and the eye is shown.

[1] Three feet seven inches to the left of the tail of the larger fish is the carving of an iguana six feet long which is shown as Fig. 11, Pl. 3, of my paper on "The Aboriginal Rock Pictures of Australia," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. x, pp. 46–70.

[2] Kangaroo-rats are represented in Figs. 13 and 14, Pl. 99, illustrating my paper on this subject in the *Report of the Australasian Association for the Advancement of Science*, Vol. vi, pp. 624–637.

[3] For other examples of nondescript or monstrous creatures drawn by the aborigines the reader is referred to Fig. 6, Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105; Fig. 10, Pl. 9, *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156.

Fig. 20. This figure, which is three feet eleven inches high and on the same rock as Fig. 26, is probably intended to represent a boy. The correct number of fingers is shown on each hand.

Fig. 21. This remarkable carving is on a large, flat rock of Hawkesbury sandstone on the western side of the road from Pymble to Pittwater, within Portion No. 23 of 320 acres in the Parish of Narrabeen.

The drawing represents a man with a weapon in his left hand, which is raised over his head. It is not clear whether the weapon is a nullanulla or a tomahawk, resembling one as much as the other. This carving is one of unusual interest, as it shows what appears to have been intended for a breast on the left side, as if the native artist had at first intended to draw a figure of a woman and had afterwards changed his mind. Or it may have been drawn to represent a dilly bag carried by a string over the right shoulder, with the bag hanging under the left arm. Again, it may have been intended to show some deformity which existed in the man it was designed to represent; or perhaps the intention was to delineate some real or legendary personage having the characteristics of both sexes.

The head contains eyes, but no other features; the feet are drawn in the usual way, but the hands are not shown. From head to foot the man stands five feet eight inches high. The rock on which this figure is carved slopes gently towards the southwest, and the bearing of the figure from feet to head is N. 50° E.

Fig. 22. This figure of a man five feet eight inches high is on the same rock as Fig. 26. The eyes and mouth are shown, and the hands have each only four fingers.

Fig. 23. This figure of a woman, one foot seven inches high, is drawn on the same rock as the last described. The hands and feet are omitted, but the paps are shown as in other carvings of females delineated on this plate. This figure is interesting on account of the comparative smallness of its size.

Fig. 24. This figure of a man six feet high is on the same flat rock as Fig. 15. The fingers are shown on the right hand, but not on the left. On the left side of the head and coming partly within it is a shield one foot nine inches long and five inches wide, with a bar across it near the middle. The penis of this figure is drawn in an unusual style, showing the foreskin.

Fig. 25. This human figure is three feet three inches high, and although the sex is not shown I am inclined to think it is intended

to represent a young girl. I have arrived at this opinion by comparing it with Fig. 23 on the same rock and with Fig. 36 in a different locality. It may also be compared with Fig. 11 Plate 9, of my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in the *Proceedings of the Royal Society of Victoria*, vii, N. S., pp. 143–156.

Fig. 26. This carving is delineated on a flat rock of Hawkesbury sandstone sloping northerly, within Portion No. 1139 of twenty-four and one-half acres in the Parish of Manly Cove. This drawing is apparently intended to represent the wombat, an Australian animal with a very short tail and heavy body. Like many other native drawings, the animal is shown much larger than the natural size. From the point of the nose to the end of the tail it measures nine feet eight inches, and across the body at the widest part it is four feet. The plate shows the figure exactly as it appears upon the rock, the usual careful measurements having been taken. Within the outline of this carving is what appears to be a snake three feet six inches long.[1]

Fig. 27. This carving, which probably represents a shark,[2] is on the same rock as Fig. 26, and is eleven feet long. There are two dorsal and one ventral fin and a fairly good tail. The nose of this fish is very pointed, a peculiarity I have observed in other native drawings. Near the mouth is a boomerang one foot eight inches long, on the concave side of which is a small oval figure. Farther on towards the tail of the fish are two other oval figures of larger size, but I am at present unable to suggest what they are intended to represent—they might conceivably be meant for eggs.

Fig. 28. This figure is on the same rock as Fig. 61, and represents a man four feet four inches high. Contiguous to his right hand are two oval figures about a foot long and nine inches across, which may have been intended to represent shields, or possibly the eggs of a bird. A similar object is shown in Fig. 61.

Fig. 29. This group of carvings is situated on the horizontal surface of several large tabular masses of Hawkesbury sandstone, all in

[1] This carving is shown as Fig. 14, Pl. 3, in my paper on "The Aboriginal Rock Pictures of Australia," in *Proc. Roy. Geog. Soc. Aust.*, Qld. Bch., Vol. x, pp. 46–70.

[2] An immense fish carved on a rock by the aborigines is shown in Fig. 15, Pl. in my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156.

close proximity to each other on the western side of the cleared road leading from Pymble along the dividing range between Cowan and Cockle Creeks, about half a mile southerly from "Bobbin" Trigonometrical Station, in the Parish of Gordon.[1]

The largest emu[2] is six feet three inches from the beak to the end of the tail, and is five feet high, in the attitude of looking for food or at something on the ground; and although the neck is rather too short, it is a very fair picture of an emu. Only one leg is delineated, and the foot is shown in continuation of the leg.

The other emu, which is much smaller, measures three feet two inches from the beak to the tail, and stands three feet five inches high. In this drawing the eye has been added, and one leg with its foot is delineated in the same way as that of the large emu.

Between the last two birds is a small one, fifteen inches from tail to head, and fourteen inches from pinion to pinion. Were it not for the presence of wings and the shortness of the neck and legs we might suppose this to be intended for a young emu to complete the picture. As it is, however, it appears to represent some bird upon the wing.

Fig. 30. This carving is also on the continuation of the same flat rock which contains Fig. 29. The figure measures two feet four inches in extreme length, one foot two inches across the fore feet and one foot four inches across the hind feet. The head is four inches long and the tail nine inches. This drawing appears to be intended for a flying squirrel, as it resembles that animal more

[1]Besides Figs. 29 to 37, inclusive, shown in this plate and now described, there are on the same cluster of rocks some other carvings which are described by me elsewhere, the positions of which are as follows: About five paces from the snout of Fig. 31 is a group representing a man and woman in the attitude of dancing. Near them is a native "dilly bag" and several human footmarks cut into the rock. For a description of this group of carvings see my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156, Pl. 9, Fig. 8.

About twenty-five or thirty paces in a southwesterly direction from the last-mentioned carvings is another group representing two men and two emus. For a drawing of this group, see Fig. 3, Pl. 2, in my paper on the "Rock Pictures of the Australian Aborigines," published in the *Proceedings of the Royal Geographical Society of Australasia*, Queensland, Vol. xi, pp. 86–105.

[2]A group of six emus are represented in Fig. 1, Pl. 2, in my paper on "Australian Rock Pictures," published in *The American Anthropologist*, viii, 268–278.

closely than any other I can compare it with. It may, however, be intended to represent some bird.

Fig. 31. This figure is delineated on the same flat rock of Hawkesbury sandstone as Fig. 29. It measures four feet five inches from the point of the nose to the tip of the tail; the head contains an eye, and there is also a dot on the ear, apparently to indicate the hollow part of it. I submit that this is intended to represent an opossum,[1] because the portion of the body is more horizontal than in figures of kangaroos and kangaroo-rats, in which the fore part of the body is always more or less elevated. The position of the tail, pointing slightly upwards, also strengthens the supposition that it is an opossum.

Fig. 32. This carving is on a flat rock of Hawkesbury sandstone, not far from the last-described carving, and appears to be intended to delineate a bird on the wing,[2] but it is difficult to suggest what bird is the likeliest to be indicated, and in trying to arrive at a definite conclusion the forked tail should not be lost sight of. From the extremity of one wing to that of the other measures three feet, and the total length from the head to the end of the tail is one foot eleven inches. It is well known that the natives had animals and birds as totems; among these may be mentioned the eagle hawk, the crow, the white cockatoo, the emu, the kangaroo and so on.

Fig. 33. This peculiar carving is executed on the same group of flat rocks as the preceding, and delineates the lower part of the body of a man, from the waist downwards, the knees being bent outwards, with the feet also in the same direction. From the outside of one knee to the outside of the other measures three feet eight inches. The figure may have been intended to indicate that the man was sitting on the rock, the rest of the body being upright and not shown; or perhaps it was intended to convey the idea that the rest of the man's body had gone into the rock, leaving this part protruding. I have seen similar figures carved upon rocks, but they are uncommon,[3]

[1] For another carving of an opossum see Fig. 7, Pl. 3, *Proc. Roy. Geog. Soc. Aust.*, Queensland, p. 67.

[2] For carvings of birds on the wing the reader is referred to Fig. 2, Pl. 99, illustrating my paper on "Rock Paintings and Carvings of the Aborigines of New South Wales," published in the *Report of the Australasian Association for the Advancement of Science*, Vol. vi, pp. 624–637.

[3] For a similar carving see Fig. 10, Pl. 2, attached to my paper on "Rock Pictures of the Australian Aborigines," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

Fig. 34. This small figure is also on the same line of rocks as Fig. 31. It is one foot seven inches high, and the same distance from hand to hand. The head is rather bird-shaped, and has an eye; there are incised curved lines reaching from the arms to the head on each side, the meaning of which I am unable to suggest.

This figure is most likely intended to denote a "piccaninny" or young aborigine, because there was room on the rock to draw a much larger figure if it had been desired. We frequently, I might say mostly, find figures of men drawn in caves which are not larger than this, but in such cases the small-sized figures are chosen on account of want of room on the cave walls.[1]

Fig. 35. This carving is on a continuation of the same flat rock as Fig. 31 and is another of those objects found in aboriginal drawings the precise identity of which it is difficult to arrive at. It is probably intended for the echidna[2] or porcupine, but I would, however, throw out the suggestion that it may be intended to represent a dilly bag. Some color is lent to this view from the lines drawn across it; the dot, which may represent the eye, is, however, against the latter theory.

Fig. 36. This carving is delineated on the continuation of the same flat rocks as the preceding, and represents a female two feet seven inches high and about the same distance across from hand to hand.[3] The arms are very long for the size of the body, and there are four fingers on each hand, but the feet are not shown. In the centre of the head is a small hole or dot, and there are two similar holes on the chest, but whether they were put there by the native artist or are merely water-worn indentations in the rock is uncertain. Above the figure there is a bird-like object which at the nearest points is two and a half inches from the head. This may be intended as an ornament to the head, or it may be where some other figure has been commenced and abandoned. The breasts are drawn in the usual way adopted by native artists, and there is a short incised line apparently intended to represent the *pubes*.

[1] A few feet from this figure is a carving of an iguana seven feet two inches long, shown as Fig. 9, Pl. 9, *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), p. 153.

[2] For similar carvings see Figs. 11 to 17, Pl. 2, *American Anthropologist*, viii, 276.

[3] For a colossal carving of a woman nearly twelve feet tall, the reader is referred to Fig. 2, Pl. 16, of my paper on "The Rock Paintings and Carvings of the Australian Aborigines," *Jour. Anthrop. Inst.*, London, Vol. xxv, pp. 145–163.

Fig. 37. This carving is also on the same flat rocks as Fig. 31. It is evidently intended to represent a male, probably a youth. It has the same bird-like head as Fig. 34, a form not uncommon in native carvings. The legs are short, but the termination of them is well defined, showing that they were originally drawn as they now appear. Near the extremity of one of the legs is a small unfinished drawing eight inches long by two inches wide.

Fig. 38. This large fish, apparently intended for a shark, is delineated on the same rock as Fig. 15; it is fourteen feet four inches long and three feet nine inches across the widest part of the body, not including the fins. It has a pointed nose like Fig. 27 and otherwise closely resembles that fish.[1]

Fig. 40. This interesting carving is delineated on the same rock on which Fig. 26 appears and represents a fish two feet nine inches long and one foot across the body at the widest part. It has a dorsal and a ventral fin and a small, well-formed tail. An incised line, similar to that marking the outline of the fish, extends from its mouth for about five feet six inches along the rock.[2] This is evidently intended as the picture of a fish caught on a line.[3]

Fig. 41 consists of a circular figure with a winding lind extending from it to another figure one foot six inches long and six inches wide. Within the former is one of those oval objects referred to in Fig. 27. Both this and the preceding carving, Fig. 40, are on the same flat rock as Fig. 26.

Figs. 39, 42 and 43. Fig. 43 I am unable to offer any explanation of at present. Fig. 39 are no doubt intended either for human hands or the paws of some animal.[4] The upper one has three fingers, the lower one four, each having a thumb in addition. Fig. 42 is, in my opinion, a human hand with part of the arm attached, and not

[1] The reader is referred to my paper on "The Rock Paintings and Carvings of the Australian Aborigines," *Journ. Anthrop. Inst.*, xxv, pp. 145–163, Pl. 16, Fig. 7, for a carving of a very large shark, 33 feet 10 inches in length.

[2] For a similar carving of a fish caught on a line see Fig. 13, Pl. 2, illustrating my paper on "The Rock Pictures of the Australian Aborigines," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

[3] Collins says he saw the natives of New South Wales fishing with a hook and line. The line was made of the bark of a small tree, and the hooks of the pearl oyster shell, which they rubbed on a stone until it assumed the shape desired.—*Account of the English Colony in N. S. Wales*, 1798, Vol. i, pp. 556–557.

[4] For a similar hand see Fig. 1 (g), Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

a foot, as might be supposed at first sight. Compare with representations of feet in Fig. 61.

Figs. 44 to 47. On the same rock as Fig. 26 are representations of fish of different sizes, ranging in length from two feet two inches to six feet. Six inches from the mouth of Fig. 45 are two lines crossing each other, one being ten inches long, the other five.

Fig. 48. This figure of a man five feet nine inches high appears on the same rock as Fig. 61 and is close to it. The eyes, mouth, and the proper number of fingers are delineated, as well as a belt round the waist. A small oval figure, similar to those seen in Fig. 27, appears close to the belt on the right-hand side.

Fig. 49. This appears to me to be part of a shield, which was left when half finished. It is two feet five inches long and ten inches wide. It is on the same rock as Fig. 47 and is close to it.

Fig. 50. This interesting drawing of a fish four feet six inches long appears on the same flat rock as Fig. 15. There are two dots for the eyes, on the same side of the head, a peculiarity of native drawing frequently seen in representations of fish.

Fig. 51 is on the same rock as the preceding, and is a very good drawing of a fish four feet five inches long.

Fig. 52 represents a shield three feet six inches long and one foot eight inches wide, and is on the same rock as the last two figures. Attention is drawn to the unusual point at the end.

Fig. 53. This figure represents a shield four feet three inches in length and one foot nine inches in breadth, with a longitudinal and a transverse subdivision. This carving is on the same series of flat rocks as Figs. 7 to 13 and is not far from them.

Fig. 54. This drawing, which is on the same rock as Fig. 26, may have been intended to represent a fish, or perhaps the skin of some animal.

Fig. 55 is on the same rock as Fig. 26, and represents a human figure five feet one inch high, the sex of which is uncertain. Five fingers are shown on each hand.

Figs. 56 and 57. Fig. 56, which is eighteen inches long, is apparently intended to represent the native tomahawk, with handle attached. Fig. 57, which is one foot nine inches long, may be either a nulla nulla or a tomahawk. These figures are carved on a mass of Hawkesburg sandstone more than an acre in extent, about five chains from the eastern side of the old road from Peat's Ferry to Sydney, and about a mile northerly from the rock containing Fig. 1.

Fig. 58. This large fish is carved on the same mass of sandstone as Fig. 1, but several yards farther south, and close to the old dray track. It measures twenty feet five inches from the snout to the farthest end of the tail, and thirteen feet from point to point of the fins. Across the larger of the fins, which appears to be the dorsal, is an incised line, such as is frequently met with on the bodies of different animals drawn by the aborigines. The two eyes are shown on the same side of the head, a mode of representing the eyes often observed in native pictures. The greatest width of the body, independently of the fins, is eight feet.[1]

Fig. 59. This representation of an eel is three feet four inches long, and five inches across the widest part of the body; from point to point of the fins measures seven inches. There are four bands or lines across the body. It is carved on the same flat rock as Figs. 56 and 57. For other carvings of eels, see Figs. 7, 8 and 9 of this plate.

Fig. 60. It is difficult to arrive at a definite conclusion as to what these figures are intended to represent. One is ten feet long, the other twelve, and they each have an average width of three inches. They occupy a position on the rock very close to Fig. 14, the end of them almost touching the right foot of the latter. Perhaps they represent spears or yamsticks; or were possibly intended for large snakes.

Fig. 61. This interesting carving is on a flat rock of Hawkesbury sandstone with Portion No. 796 of 9 ac. 2 r. 3 p., Parish of Manly Cove. It represents a man six feet high, with a belt round the waist and bands round the arms near the shoulder, similar to those seen in Fig. 1. Within the outline of the body is a very good representation of a human foot, twelve inches long, four inches across the toes, and three inches across the heel.[2] About three feet behind the heel of the last-mentioned figure is another human foot, not so perfect as the first, twelve inches long and having only four toes. Eleven inches farther away in the same direc-

[1] For a monstrous carving of a shark, nearly thirty-nine feet long, see my paper on "The Rock Paintings and Carvings of the Aborigines of N. S. Wales," published in *Rep. Australas. Assoc. Adv. Sci.*, vi, pp. 624–637, Pl. 99, Fig. 30.

[2] Human footmarks carved on rocks are represented in Fig. 8, Pl. 9, illustrating my paper on "Aboriginal Rock Paintings and Carvings in New South Wales," published in the *Proceedings of the Royal Society of Victoria*, Vol. vii (N. S.), pp. 143–156.

tion is an oval object, but what it is intended to represent I am at present unable to offer an explanation. The two last-described figures are shown in their relative positions to each other, but are not so in reference to the man. They are shown above the head of the latter on the plate to fill out a vacant space, but a careful reading of this description will indicate their true position.

ON THE TRANSITIVE SUBSTITUTION GROUPS THAT ARE SIMPLY ISOMORPHIC TO THE SYMMETRIC OR THE ALTERNATING GROUP OF DEGREE SIX.

BY G. A. MILLER, PH.D

(*Read May 7, 1897.*)

When the degree of a symmetric or an alternating group is not 6 we can obtain all the simple isomorphisms of the group to itself by transforming it by means of the substitutions of the symmetric group of the same degree. In other words, we can construct only one intransitive group of degree mn and order n ! or n ! ÷ 2, whose m transitive constituents are respectively the symmetric or the alternating group of degree n, n ∓ 6.[1] Hence the number of transitive substitution groups that are simply isomorphic to the symmetric group of degree n (n ± 6) is equal to the total number of substitution groups (transitive and intransitive) that can be constructed with n letters and whose order is less than n ! ÷ 2, while the number of those that are simply isomorphic to the alternating group of this degree is equal to the number of all the other positive groups that can be constructed with n letters.[2]

As nearly all the groups that can be constructed with n letters are subgroups of larger groups that do not involve the symmetric or the alternating group of degree n and whose degree < n + 1, the transitive substitution groups that are simply isomorphic to the

[1] Hölder, *Mathematische Annalen*, Vol. xlvi, pp. 340, 345; cf. Miller, *Bulletin of the American Mathematical Society* (1895), Vol. i, p. 258.

[2] Dyck, *Mathematische Annalen*, Vol. xxii, p. 90; cf. Miller, *Philosophical Magazine* (1897), Vol. xliii, p. 117.

symmetric or the alternating group of degree n are, as a rule, non-primitive.[1] Those that are simply isomorphic to the alternating group are simple when $n \neq 4$ and can therefore contain no substitution besides identity that leaves all of their systems of non-primitivity unchanged. The first group of this kind is of order 60 and degree 12. Its elements can be divided in only one way so that each division is a system of non-primitivity. Even when such a group has different sets of systems of non-primitivity it cannot contain any substitution besides identity that leaves all the systems of non-primitivity of any set unchanged since it contains no self-conjugate subgroup except identity.

The following well-known group illustrates that the elements of some non-primitive groups can be divided into different sets of systems of non-primitivity, so that the groups contain no substitution besides identity that leaves all the systems of one set unchanged while they contain other substitutions that leave those of another set unchanged.

1	ad. bf. ce
abc. def	ae. bd. cf
acb. dfe	af. be. cd

This group contains no substitution besides identity that leaves all the systems of non-primitivity of any one of the following three sets unchanged ;

a,d : b,e : c,f a,e : b,f : c,d a,f : b,d : c,e

while three of its substitutions leave the systems of the following set unchanged ;

a,b,c : d,e,f.

The other regular group of order 6 may serve to illustrate that the elements of some non-primitive groups cannot be divided into systems of non-primitivity so that the groups contain no substitution besides identity that leaves all the systems unchanged.

A non-primitive group that is simply isomorphic to the symmetric group of degree n ($n \neq 4$) contains only one selfconjugate subgroup besides identity. If its largest subgroup whose degree is less than the degree of the group corresponds to a positive subgroup of the symmetric group, its selfconjugate subgroup must be intransitive and it must have two systems of non-primitivity. If the given sub-

[1] Cf. Maillet, *Comptes Rendus*, Vol. cxix, p. 362.

group corresponds to a positive and negative subgroup of the symmetric group the selfconjugate subgroup of order $n! \div 2$ is transitive, and the non-primitive group contains no substitution besides identity that leaves all the systems of any of the possible sets of systems of non-primitivity unchanged. We thus obtain composite non-primitive groups that do not contain any substitution besides identity that leaves all the systems of any of the possible sets of systems of non-primitivity unchanged. The first group of this kind is of order 120 and degree 15.

Both the symmetric and the alternating group of degree 6 contain $6!$ simple isomorphisms to themselves that cannot be obtained by transforming the groups by means of any substitutions whatever. If we regard these groups as operation groups of orders $6!$ and $6! \div 2$ respectively we can find an operation group of order $2 \times 6!$ which transforms both of them into all the possible simple isomorphisms to themselves.[1] This group is simply isomorphic to the group of all simple isomorphisms of the given operation groups to themselves and contains the symmetric group of order $6!$ as selfconjugate subgroup.

That the smallest operation group which transforms a given operation group into all the possible simple isomorphisms to itself is always simply isomorphic to the group of all these simple isomorphisms may be easily proved as follows. We represent the given operation group of order g by the regular substitution group. The largest group of degree g that contains it as a selfconjugate subgroup transforms it into all the possible simple isomorphisms to itself and has a g, 1 correspondence[2] to the group of these simple isomorphisms. Its subgroup which contains all the substitutions that do not involve one of its g elements must be simply isomorphic to the group of all the given simple isomorphisms since all the substitutions that are commutative to each of the substitutions of the given regular group form a regular group of degree g.

It is known that the symmetric or the alternating group of degree 6 can be made simply isomorphic to itself by placing the group of order 120 or 60 and degree 6 in correspondence to a group of degree 5. All the substitutions of order 3 in such a 1, 1 correspondence are of degree 9, for it is evident that some are of this degree and that all must have the same degree because all the subgroups of

[1] Cf. Frobenius, *Sitzungsberichte der Akademie zu Berlin*, 1895, p. 184.

[2] Jordan, *Traite des Substitutions*, p. 60.

order and degree 3 as well as those of order 3 and degree 6 are conjugate in the symmetric and in the alternating group. From this it follows that the substitutions of degree and order 2 must correspond to those of degree 6, and hence that all the substitutions of order 2 in such a 1, 1 correspondence are of degree 8.

The Fifteen Transitive Substitution Groups that are Simply Isomorphic to (abcdef) pos.

We shall consider these groups in the order of their degrees, beginning with those of the highest degrees. There is one group of degree 360, viz., the regular group. We represent it by G_1. As there is only one positive group of order[1] 2 and the two groups of order 3 can be made to correspond there is one transitive group (G_2) of degree 180 and one (G_3) of degree 120 that are simply isomorphic to (abcdef) pos. Since the given group of order 2 is transformed into itself by 8 positive substitutions and the given groups of order 3 are transformed into themselves by 18 positive substitutions G_2 and G_3 are respectively of class[2] 176 and 114.

There is only one positive cyclical group of order 4 and the two positive non-cyclical groups of this order can be made to correspond since the transitive one cannot occur in $(abcde)_{10}$, and hence it can also not occur in $(abcdef)_{60}$. The group (G_4) of degree 90 whose 4 substitutions that do not contain a given element form a cyclical group is of class 88 since there are only 8 positive substitutions that transform the given positive group of order 4, or its subgroup of order 2, into itself. The other group of this degree (G_5) is of class 84. In both of these groups, the subgroup which contains the four substitutions that do not involve a given element contains three substitutions of the same degree. Since there is only one group of order 5 there is only one group of degree 72 (G_6) that is simply isomorphic to (abcdef) pos. It is of class 70.

Since only one of the two positive groups of order 6 is found in (abcde) pos., they can be placed in correspondence and there is only one transitive group (G_7) of degree 60 that is simply to (abcdef)

[1] We consider only those groups whose degree does not exceed 6. A list of these groups is given by Prof. Cayley, *Quarterly Journal of Mathematics*, Vol. xxv, p. 71.

[2] The class of a substitution group is the degree of its substitution that permutes the smallest number of elements besides identity. Cf. Jordan, *Lionville's Journal*, 1871.

pos. We proceed to find the forms of the substitutions of the subgroup of G_7, which contains all its substitutions that do not involve a given element. Its substitutions of order 3 clearly consist of 19 distinct cycles of degree 3. If we arrange the substitutions of (abcdef) pos., according to [(abc) all (de)] pos., or (abc. def) all, we obtain 4 rows of substitutions whose — 1 powers transform any one of the substitutions of order two in either of these groups into substitutions of the same group. Hence the corresponding substitution of G_7 is of degree 56, and this is also the class of G_7. Its subgroup which includes the substitutions that do not involve a given element contains therefore 2 substitutions of order 3 and degree 57, 3 of order 2 and degree 56, and identity.

Since there is only one positive group of each of the orders 8, 9, 10 there is only one transitive group of each of the degrees 45, 40, 36 that is simply to (abcdef) pos. We shall denote these groups by G_8, G_9, G_{10}. Their classes are respectively 40, 36, 32. The two positive groups of order 12 lead to only one group (G_{11}) since one of them occurs in (abcde) pos. and its substitutions of order 3 are also of degree 3. G_{11} is of degree 30 and class 24. Half of its substitutions of order 3 are of degree 30 and the rest of degree 24. All its substitutions of order 2 are of degree 28. There can be only one transitive group of degree 20 (G_{12}) that is simply isomorphic to (abcdef) pos. since there is only one positive group of order 18. All of its 80 substitutions of order 3 are of degree 18 and its 45 substitutions of order 2 are of degree 16. As the other substitutions are of degree 20 G_{12} is of class 16.

There can be only one transitive group of degree 15 (G_{13}) that is simply isomorphic to (abcdef) pos. since the two positive groups of order 24 must evidently correspond in the simple isomorphism of (abcdef) pos. to itself in which all the substitutions of order 3 are of degree 9. G_{13} contains the following substitutions, besides identity, whose degrees are less than 15 : 40 of order 3 and degree 12, 45 of order 2 and degree 12, 90 of order 4 and degree 14. Hence it is of class 12. The group of degree 10 (G_{14}) that depends upon the positive group of order 36 contains 90 substitutions of order 3 and degree 9, 45 of order 2 and degree 8, 90 of order 4 and degree 8. The rest are of degree 10 with the exception of identity. The group (G_{15}) which depends upon either of the two groups of order 60 is (abcdef) pos. itself.

Since each of the three groups

(abcde) pos. $\quad$ $(abcdef)_{36}$ $\quad$ [(abcd) all (ef)] pos.

is a maximal subgroup of (abcdef) pos. the corresponding groups, viz., G_{15}, G_{14}, G_{13} are primitive. The other 12 are non-primitive. As they are simple groups they cannot contain any substitution besides identity that leaves all the systems of non-primitivity unpermuted. If we arrange the substitutions of (abcdef) pos. according to (abcde) pos. we may letter the rows in such a manner that they are permuted according to a substitution that is identical to the particular substitution into which the entire group is multiplied. This is clearly not the case when they are arranged according to $(abcdef)_{60}$ since the necessary and sufficient condition that a given substitution leads to a substitution whose degree is less than the degree of the simply isomorphic transitive group is that it is conjugate to some substitution in the group which forms the first row. G_{13} is simply transitive since its order is not divisible by 14. G_{14} and G_{15} are clearly multiply transitive.

The Thirty-five Transitive Substitution Groups that are Simply Isomorphic to (abcdef) all.

The subgroups which correspond in a simple isomorphism of (abcdef) pos. to itself correspond also in some simple isomorphism of (abcdef) all to itself. Hence each group that leads to a transitive group of degree n that is simply isomorphic to (abcdef) pos. leads also to a transitive group of degree 2n that is simply isomorphic to (abcdef) all. We observed above that the latter groups contained two systems of non-primitivity and that they are the only groups which are simply isomorphic to (abcdef) all and have this property. Hence 15 of the non-primitive groups that are simply isomorphic to the symmetric group of degree 6 contain two systems of non-primitivity. Their degrees are as follows:

720, 360, 240, 180, 180, 144, 120, 90, 80, 72, 60, 40, 30, 20, 12.

The remaining 20 transitive groups that are simply isomorphic to (abcdef) all depend upon subgroups that involve negative substitutions. We shall therefore confine our attention to such subgroups. As the methods are similar to those employed in what precedes we shall be more brief in our explanations. The two groups of order 2 lead to the same transitive group (G_{14}) since all the substitutions

of order 2 in some of the simple isomorphisms of (abcdef) all to itself are of degree 8, as observed above. G_{16} is of degree 360 and class 336.

The two groups of order 4

$$(ab)\ (cd) \qquad [(abcd)_4\ (ef)] \text{ dim.}$$

must correspond in some of the simple isomorphisms of (abcdef) all to itself for the reason just given. They therefore lead to the same group of degree 180 (G_{17}). Since the largest group that transforms (ab. cd) (ef) into itself must also transform each of its substitutions into itself this group could not correspond to either of the preceding groups in any of the given isomorphisms. It therefore leads to a different group of degree 180 (G_{18}). It is evident that (abcd) cyc. leads to another group of this degree (G_{19}). The two cyclical as well as the two non-cyclical groups of order 6 must correspond in the simple isomorphism of (abcdef) all to itself in which the substitutions of order 3 are of degree 9. Hence these lead to only two groups of degree 120 (G_{20}, G_{21}).

The two groups of order 8 which contain no substitution whose order exceeds 2 must correspond in the isomorphisms in which the substitutions of order 2 are of degree 8. Hence they lead to the same group of degree 90 (G_{22}). In the same isomorphisms $(abcd)_4$ must correspond to $[(abcd)_4\ (ef)]$ dim. with respect to (abcd) cyc. We represent the group which depends upon either of these two groups by G_{23}. Each of the remaining two groups of order 8

(abcd) cyc. (ef), $[(abcd)_4\ (ef)]$ dimidiated with respect to (ab) (cd)

leads to a transitive group of degree 90 that is simply isomorphic to (abcdef) all. We represent these two groups by G_{24} and G_{25} respectively. The former of the given groups of order 8 is the only one that is commutative and contains operations of order 4 and the latter is the only one that is non-commutative and contains operations of order 4 and degree 6. On account of these properties each of these groups must correspond to itself in all the possible simple isomorphisms of (abcdef) all to itself.

The two groups of order 12 must correspond in some of these simple isomorphisms since the substitutions of order 3 are of degree 3 in the one and of degree 6 in the other. Hence they lead to the same group of degree 60 (G_{26}). As there is only one group of order 16 there is only one group of degree 45 (G_{27}). Since the

subgroups of degree 6 and order 3 in $(abcdef)_{18}$ are self-conjugate while those of degree and order 3 are conjugate, this group must correspond to the other group of order 18 in the isomorphism in which all the substitutions of order 3 are of degree 9. Hence there is only one group of degree 40 (G_{28}). The single group of order 20 leads to a group of degree 36 (G_{29}). It is evident that (abcd) all and $(\pm abcdef)_{24}$ as well as (abcd) pos. (ef) and $(abcdef)_{24}$, lead to the same group. These two groups (G_{30} and G_{31}) are of degree 30.

The transitive and the intransitive group of order 36 lead to the same group of degree 20 (G_{32}) for the same reason as was employed to show that the transitive and the intransitive group of order 18 lead to the same group. The groups which we employed so far are non-maximal subgroups of (abcdef) all. Hence each of the 32 groups given above is non-primitive. Only the first fifteen of them contain substitutions which leave all the systems of non-primitivity unchanged. It remains to find the three primitive groups that are simply isomorphic to (abcdef) all.

The one of the highest degree (G_{33}) depends upon either one of the following groups

$$(abcdef)_{48} \qquad (abcd) \text{ all } (ef)$$

It is therefore of degree 15. The next (G_{34}) depends upon the single group of order 72 and hence is of degree 10. The last (G_{35}) depends upon (abcde) pos. or upon $(abcdef)_{120}$. This is (abcdef) all itself. G_{35} is simply transitive since its order is not divisible by 14. As it contains 48 substitutions that transform each of the 7 substitutions of the form ab. cd. ef. contained in $(abcdef)_{48}$ into itself it is of class 8. We have already observed that the self-conjugate subgroups of G_{34} and G_{35} are multiply transitive, hence the groups themselves must be multiply transitive. Their classes are 6 and 2 respectively.

Paris, April, 1897.

Adjourned Stated Meeting, May 13, 1897.

The Treasurer, Mr. PRICE, in the Chair.

Present, 19 members.

The following papers were read:

"On the Geology of the Paleozoic Area of Arkansas South of the Novaculite Region," by George H. Ashley, Ph.D., with an Introduction by John C. Branner, was read by title.

"Stellar Dynamics," by Mr. Luigi D'Auria.

A letter was read from the Biological Faculty of the University of Pennsylvania, asking the Society to appoint a representative of this Society to make provision for a meeting memorial of the late Prof. E. D. Cope, and the President of the Society was requested to appoint such a representative.

Prof. Doolittle moved "that a Committee of five, consisting of Dr. Pepper, Hon. George F. Edmunds, Dr. Persifor Frazer, Dr. T. Hewson Bache and Hon. H. A. DuPont be appointed to consider and report to the American Philosophical Society on the matter of a Franklin Memorial to celebrate the Bicentennial Anniversary of Benjamin Franklin's birth, in 1906." Adopted.

A letter from the Academy of Natural Sciences of Philadelphia requesting the deposit with it of the various Herbaria in the possession of this Society, was laid before the Society In connection therewith the Curators offered the following report:

The Curators recommend that they be authorized to deposit with, and take receipt from, the Academy of Natural Sciences, the botanical collection of Lewis & Clarke, the Short and Muhlenberg, the Herbarium Americanum, and such other botanical collections now in the Society's possession, on the condition named in the letter from the Curators of the Academy, that they be kept as separate collections in the Herbarium of the Academy, properly cared for and returned on demand.

The recommendation of the Curators was adopted.

The Society was then adjourned by the presiding officer.

GEOLOGY OF THE PALEOZOIC AREA OF ARKANSAS SOUTH OF THE NOVACULITE REGION.

BY GEORGE H. ASHLEY, PH.D.,
Assistant Geologist.

WITH AN INTRODUCTION BY JOHN C. BRANNER.

(*Read May 13, 1897.*)

INTRODUCTION.

In 1890–92 Dr. George H. Ashley, the author of the present paper, was entrusted with the study of that part of the Paleozoic region of southwestern Arkansas lying between the Lower Silurian Novaculite area or the Ouachita uplift on the north, and the Cretaceous area on the south. This paper gives the principal results of Dr. Ashley's work. Properly speaking it is a part of the official reports of the Geological Survey of Arkansas, but the survey was abolished by the Legislature in 1893, and no provisions were made for printing the several unpublished volumes.

Mr. Ashley was ably assisted during one field season by Prof. A. H. Purdue, now Professor of Geology at the Arkansas Industrial University, and other valuable additions were made to the work by Mr. John H. Means, who as assistant on the State Survey has worked up the geology of the Lower Coal Measures north of the Ouachita uplift. Some notes were also furnished by Dr. J. P. Smith, formerly assistant geologist on the Arkansas Survey, now Professor of Paleontology in the Leland Stanford, Jr., University. The northern border of the Cretaceous rocks was traced by Dr. O. P. Hay.

The limited time that could be spent upon the geology of the region discussed in this paper, the folded and faulted condition of the rocks, the absence of fossils and the lack of good maps have made it impossible for the author to enter into details regarding the geologic history of the area.

The divisions I have made of the rocks and the reasons for making them are accepted, not as altogether satisfactory, but simply as the best that can be offered under the circumstances. The beds I have called the base of the Coal Measures are the novaculite conglomerates exposed at Hot Springs. The reason for considering

these beds as the top of the Lower Silurian or the bottom of the Coal Measures is simply that the novaculites, as considerable beds, end abruptly with this stratum, and because this bed is a conglomerate. It will be seen that there are some thin and unimportant beds of novaculite above this horizon, but they are no more to be compared with the novaculites below it than are the coal beds of the Devonian to be compared with those of the Carboniferous.

So far as I can judge from my own observations there is no marked unconformity between the Lower Silurian rocks and the Lower Coal Measures rocks, and that in spite of the fact that there are no Devonian rocks known to be such in this part of the State. The conglomerate, however, suggests the possibility of such an unconformity, and it is quite possible that the disturbed condition of the rocks has caused such a gap to be overlooked.

Mention is made at several places of a stratum of supposed igneous rocks interbedded with the sedimentary ones, and assumed by Dr. Ashley to be everywhere at the same horizon. There is some doubt in my mind as to whether this bed is everywhere the same, and also as to whether it is really igneous. There is no doubt but that the bed discovered by Dr. J. P. Smith in 5 south, 32 west, section 1, is a tuff, but at other places the rock is so changed by decomposition that it is not possible to say with certainty what the original materials were. It is also suggested by the author that these beds are to be correlated with similar rocks supposed to be volcanic tuffs and found about Cushman, Independence county, in the northern part of the State. But this north Arkansas bed turns out to be a phosphate deposit, and a chemical analysis of one of Dr. Ashley's specimens from southwest Arkansas shows it to contain an equivalent of nine per cent. of calcium phosphate.[1]

To the little proof here given of the age of these Lower Coal Measures rocks should be added that I have found Calamites in this series on the west bank of the Ouachita river in 5 south, 18 west, section 32. Attention should also be directed to the notes of Prof. C. S. Prosser on the "Lower Carboniferous Plants from the Ouachita Uplift," published in the *Novaculite Report of the Arkansas Survey* (Vol. iii, 1890, pp. 423, 424). Prof. Prosser's notes are upon fossils found north of the region described in the present

[1] See "The Phosphate Deposits of Arkansas," by John C. Branner, *Trans. Amer. Inst. Mining Engineers*, September, 1896.

paper, but the structure of the region shows that they are from rocks occupying the same geologic horizon.

The general structural features of the Ouachita uplift are so much like those of certain parts of the Appalachian structure that one naturally assumes at the outset that we have here an Appalachian type, and indeed a part of the original Appalachian folding. It cannot be stated positively that this is not the case, but it is my own opinion that the Ouachita uplift is the structural equivalent, not of the Appalachians, but of the Nashville Silurian basin and of the Cincinnati arch. To be sure the Ouachita anticline is closely pressed, while the Nashville and Cincinnati folds are very gentle. This difference is, however, a matter of structural detail only. The equivalent of the Appalachian chain and the source from which the Lower Coal Measures sediments of south Arkansas appear to have been derived (in part) was a continuation across the present Mississippi drainage of the pre-Cambrian rocks of Alabama and Georgia, etc. This region, that is the gap through which the Mississippi river now flows, has been lowered, partly by erosion, but chiefly by downward orographic movements and it is now buried beneath the Cretaceous and Tertiary sediments of south Arkansas and of north Louisiana and Texas.

This hypothesis seems to be borne out by the following facts:

I. The fossils found on the south side of the Ouachita anticline are coal plants like those from the Cumberland plateau of east Tennessee, eastern Kentucky, and West Virginia.

II. The sediments thicken and become coarser to the south as one leaves the Ouachita uplift (Ashley) just as in the upper Ohio valley they thicken and become coarser east of the Cincinnati arch.

III. In central Texas, northwest of Austin, is an Archean and Cambrian area which appears to be the southwestern end of the old Appalachian chain, and north of it are Carboniferous rocks.

IV. If the Cincinnati, Nashville and Ouachita arches are assumed to be the same general fold, this line is found to continue into Indian Territory and Oklahoma, and the arch as a whole is parallel with the Appalachian system save across the break made by the present Mississippi river depression where the same conditions would be expected.

V. The peneplain south of the Ouachita mountains and on which the Cretaceous beds were deposited slopes toward the Mississippi.

VI. The Arkansas river drainage formerly (in Carboniferous and

Permian times) flowed westward, but it has been reversed and now flows east and southeast.

VII. The igneous rocks of Arkansas and Texas are mostly along what appears to be the edge—possibly faulted—of this depression.

I have not thought it necessary to exclude or suppress in the present paper statements in conflict with other publications made by the Geological Survey of Arkansas. Reference is here made to the differences between the structural details as worked out by Dr. Ashley and those represented by Dr. Theodore B. Comstock on the map accompanying his report on gold and silver. No geologist with the two maps before him can have any doubt about which is right. It should be said, however, in defense of Dr. Comstock, that the time he could devote to the study of the region on which he had to report was very limited; and in defense of the publication of his map, that the report giving the economic results of his work (and these were correct and of great importance) was so tied to the theory of the structural lines put down on his maps that it was quite impossible to separate the two.

JOHN C. BRANNER,
Formerly State Geologist of Arkansas.

I. GEOLOGIC AND GEOGRAPHIC POSITION.

If in any of the Atlantic or Gulf States, one start from some point on the coast and travel inland, he will, in most cases, observe at one point a striking change both in the topographic and geologic features of the land. He has been traversing at first low-lying, then somewhat more elevated, stretches of level country, characterized, aside from its low elevation above the sea level and comparative flatness, by sluggish, meandering rivers, a luxuriant timber growth, the softness and horizontality of the rocks, consisting of unconsolidated clays, sands, gravels, etc., with an occasional hard layer, and by the freshness of the fossil remains. But as one passes the point mentioned, he comes upon a region of higher altitude, frequently or generally mountainous, with rapid rivers, more hardy but less dense timber growth, the underlying strata being highly consolidated, frequently crystalline limestones, sandstones, shales and granites, in some regions horizontal, in others highly folded and distorted.

A study of the geology on either side of the line of division shows that the region on the coast side is of comparatively recent

origin, having been deposited since the close of the Carboniferous age; the harder rocks on the landward side having been deposited during the Carboniferous and preceding ages. The former, which includes the Mesozoic and Cenozoic, has been termed the Neozoic addition. The line between the two has been traced down the Atlantic coast and through northern Georgia, Alabama and Mississippi, thence following the Tennessee river into southern Illinois, where it turns, crossing the Mississippi near Cairo and running approximately southwest on the west side of the St. Louis, Iron Mountain and Southern Railway nearly to Arkadelphia, where it turns westward and follows an irregular line into the Indian Territory and Texas.

The region described in the present report lies in a belt just north of that portion of the above line running west from Arkadelphia. To define and locate it more clearly we shall first review the general geologic features of the region from this line to the Arkansas river as shown in the reports already published upon that area.[1]

The history thus revealed is briefly:

1. A long period of deposition running from early Silurian times through the Carboniferous age, and the accumulation of deposits of great thickness.

2. These deposits give way to mountain-making forces and becoming much folded are lifted into an anticline, called by Dr. Branner the "Ouachita uplift." The axis of this anticline is an approximately east and west line running from Little Rock west well into the Indian Territory.

3. A period of erosion during which the uplift is cut down until the Silurian strata are exposed along the axis. The later beds are successively exposed as one goes away from the axis of uplift.

4. A period of depression and deposition upon the southern slope of the Ouachita uplift. During this period, and up to the present time, there has been a series of oscillations of level, resulting in slight nonconformity between the strata.

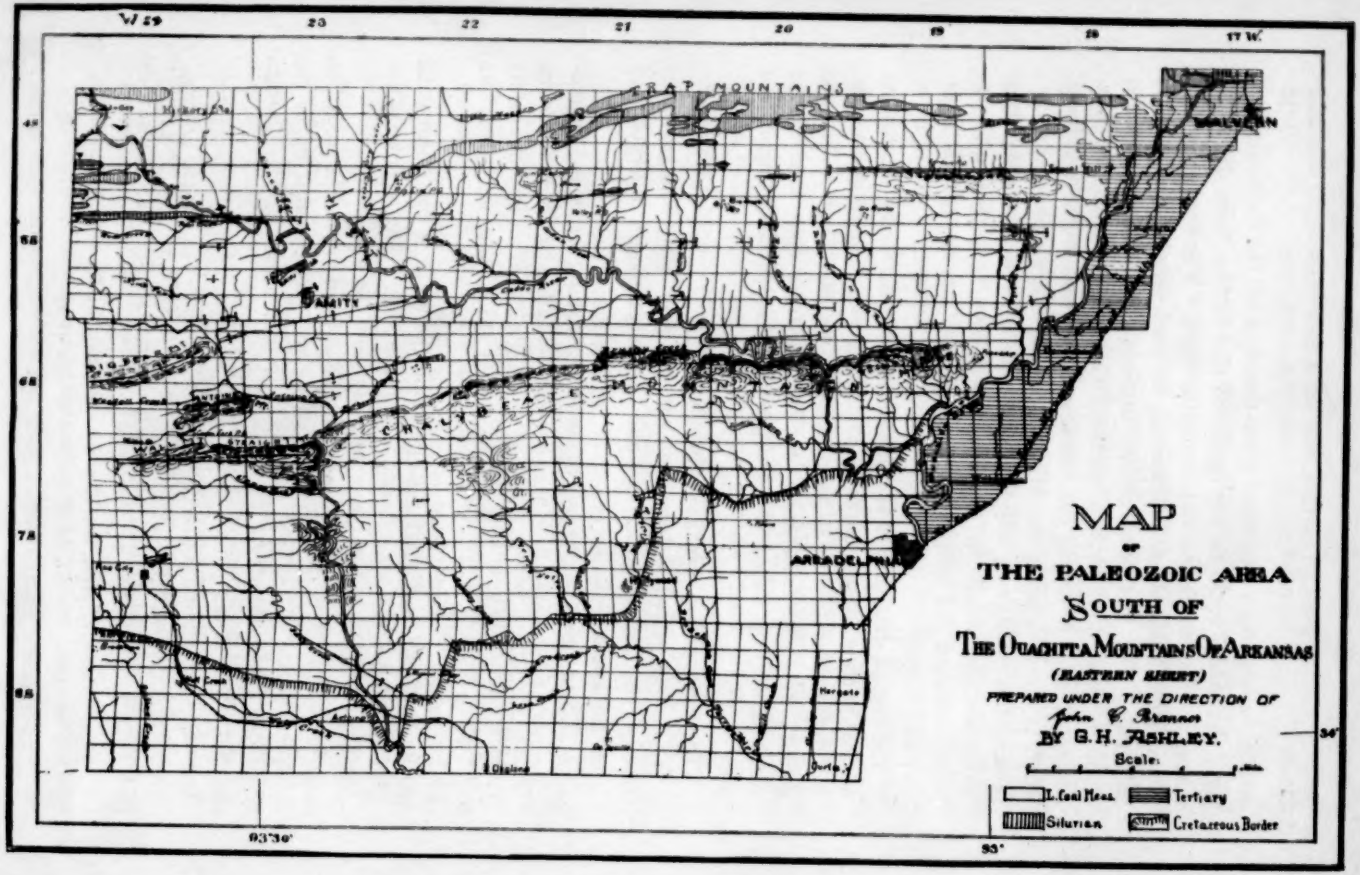
The rocks are now exposed in the following order:

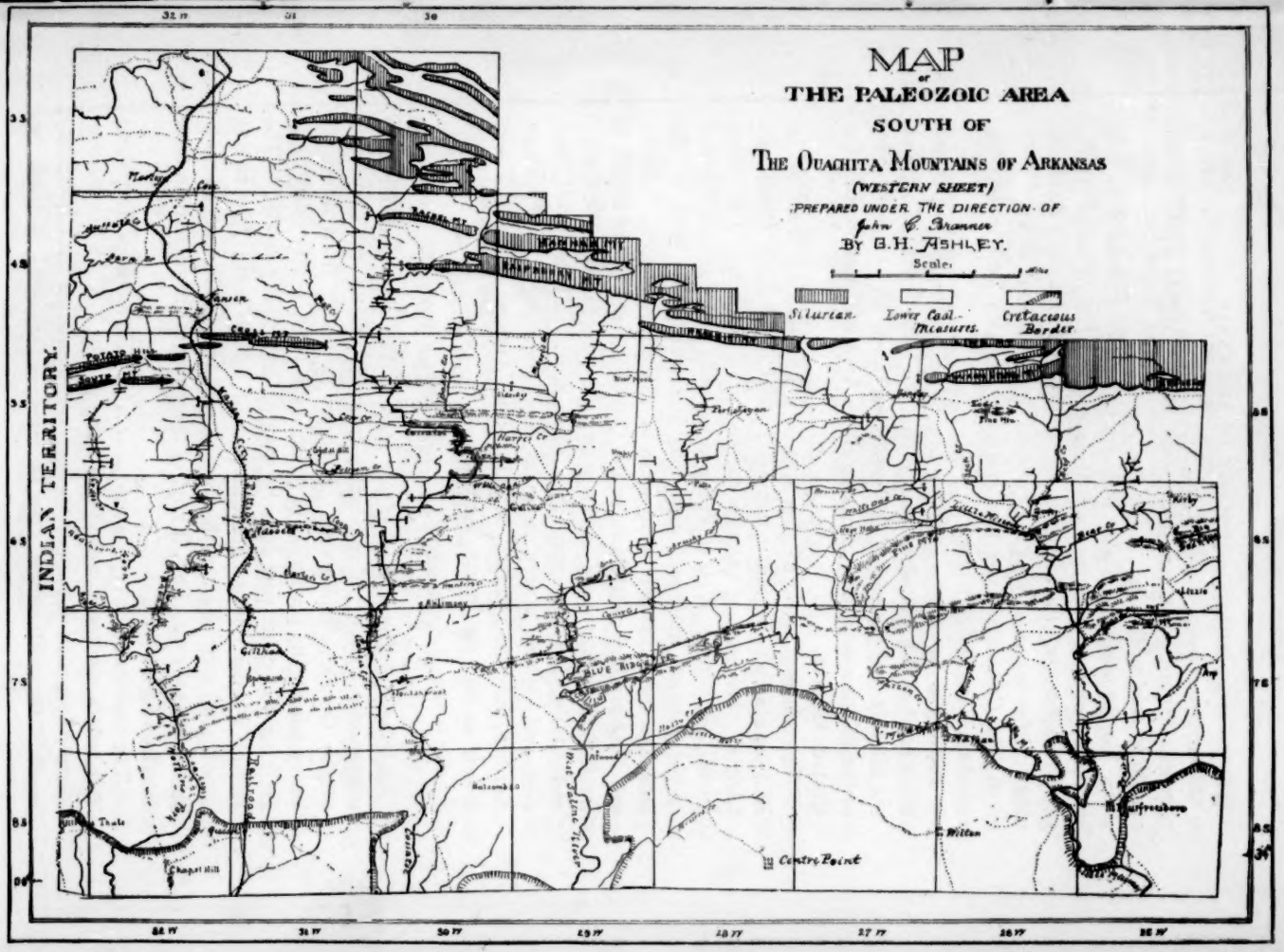
1. A belt of Silurian exposures running from Little Rock a little south of west to Dallas, of which the novaculites[2] are prominent

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. iii; for 1890, Vols. i and iii.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii.

PROC. AMER. PHILOS. SOC. XXXVI. 155. P. PRINTED AUGUST 5, 1897.


W 29
23
22
21
20
19
18
17 W.
RAT MOUNTAINS
CHALYBEATE MOUNTAIN
ARKADELPHIA
MAP
OF
THE PALEOZOIC AREA
SOUTH OF
THE OUACHITA MOUNTAINS OF ARKANSAS
(EASTERN SHEET)
PREPARED UNDER THE DIRECTION OF
John C. Branner
BY G. H. ASHLEY.
Scale:
L. Coal Meas.
Tertiary
Silurian
Cretaceous Border
93°30'
93°


MAP
OF
THE PALEOZOIC AREA
SOUTH OF
THE OUACHITA MOUNTAINS OF ARKANSAS
(WESTERN SHEET)
PREPARED UNDER THE DIRECTION OF
John C. Branner
BY G.H. ASHLEY.
Scale.
Silurian.
Lower Coal Measures.
Cretaceous Border.
INDIAN TERRITORY.
BLUE RIDGE
Centre Point
Chapel Hill
Milton
Murfreesboro

layers. Owing to minor folds some of the higher strata are exposed in this belt.

2. To the north the higher beds are successively exposed, ending in the upper or productive Coal Measures near the Arkansas river.

3. To the south the higher strata are exposed for a short distance, but still further south they are covered by Cretaceous rocks.

4. The Cretaceous and the overlying Tertiary beds extending southward to the State line.

The strata we are to consider are those mentioned under the third head of the preceding paragraph: the beds deposited between the Silurian and the end of Carboniferous times, and exposed south of the Silurian exposures of southwestern Arkansas, and north of the Cretaceous area.

The northern limit of this area is a line starting from Social Hill in 4 S., 18 W., and touching Point Cedar, Rock Creek and Langley, then passing through the centre of township, 4 S., range 30 W., to Potter. West of Potter these beds swing around the end of the Silurian anticlinal nose and unite with the beds of the same age and character lying north of the Silurian area. On the east the boundary nearly follows the Ouachita river to the mouth of the Caddo river, thence on the south the line follows the Caddo and up Big DeGray creek, then turns south to Hollywood, then west, and follows a very irregular line, touching Clear Springs, Antoine, Royston, Nathan, Muddy Fork, Atwood, Ultima Thule, and so on into the Indian Territory.

II. Salient Features of the Region.

A General Description of the Area.—The region under consideration is a rocky, hilly country stretching along the south side of the Ouachita mountains. It varies in width from fifteen to thirty miles; the part lying in Arkansas is about ninety miles long. It is for the most part densely wooded and thinly settled. The surface is broken into a great number of valleys and ridges having an east and west trend, with a few narrow and usually rugged north and south valleys. Few, if any, of these ridges are more than three hundred feet in height.

The most common type is a ridge or table land having a steep north face, while the south side slopes away gently. A few are narrow, sharp ridges with uneven crests and steep flanks on both north and south sides. All others may be taken as variations of these two

types. Sometimes the ridges can be followed for a score or two of miles; then again a ridge is prominent only where it approaches a north and south stream, and as it recedes from the stream the valleys on either side become shallower until the ridge coalesces with those next north and south of it, and is lost as a distinct ridge.

All around the southern edge of the region, the topography is of quite a different nature. It appears to be very level, though having a slight rise to the north. This level strip averages half a dozen miles in width. Its northern edge is irregular and seems to be governed by the erosion of east and west valleys into what might have been its northward extension. Novaculite gravels cover this flat region. Sandstone is the most common rock, though occasionally in the valley there are considerable beds of shale.

It is a matter of common observation among those living in the region, that the rocks almost invariably "stand on end."

While much of the region is very stony, the rocks are mostly in the form of loose blocks and boulders, but little of it being found in place and most of that is in the beds of streams.

Though the strata usually dip to the south, in some places they dip to the north. The dip is usually high, more often over than under 45°.

Just north of this Carboniferous region are the high hills or mountains of the Ouachita mountain system. The rocks in these mountains are novaculites associated with shales and sandstones.[1]

To the south these Paleozoic beds are overlaid unconformably by sands, marls and limestones of the Cretaceous.

In the eastern part of the region under discussion the main streams run east or southeast and the branches run south. The streams are not rapid and the valleys are frequently quite broad. Westward the main drainage swings around towards the south, the branches run in east-west channels, and the streams are rapid, with narrow, sometimes precipitous banks.

From an economic standpoint the most valuable product of the area is the timber. Hard and soft woods of excellent qualities abound in every part of the region.

Little of value was discovered in the line of building or other stone, nor is the region rich in ores, though small quantities of pay ore, mostly antimony, have been found in the southwestern part of the area.

Corn and cotton are the principal crops. The country as a whole is well watered and healthful.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii.

Much of the land is too broken for cultivation except for some hillside crop like grapes, which are said to do well here.

While most of the soil is sandy and not very rich, there is much good land along the streams, particularly in the eastern part. In the western part of the region most of the available land is on the divides.

Conclusions.—A summary of the conclusions deduced from a study of the features above touched upon can best be given as a history of geologic events in the region.

The Periods of Deposition.—The deposition of the rocks took place before the end of the Carboniferous age, and as the rocks are of both Silurian and Carboniferous ages, it must have been during these times that these sediments were laid down.

The Lower Silurian beds are the novaculites, with the accompanying shales and sandstones. The Carboniferous strata are sandstones and shales, with which occur a little grit, novaculite and some other rocks. No nonconformity has been found between the two sets of beds. The Silurian beds are believed to underlie the sandstones of the Carboniferous over all of the region, though they have been recognized at only one place.

The original thickness of the Carboniferous strata is not known, nor is it known whether the whole or only a part of the Carboniferous series was laid down over this territory. The beds remaining are thought to belong mostly to the Lower Coal Measures. The only fossils found are a few fragments of plants. No satisfactory columnar section has been obtained of the beds, but their thickness cannot be less than four or five thousand feet.

Period of Folding.—At the end of the Carboniferous age, or possibly before it, the beds of sediment in southwestern Arkansas and the adjacent portion of the Indian Territory began to yield to an apparently horizontal pressure. Gradually the great Ouachita uplift rose, and the upper beds began to fold. This continued until the upper beds were folded closely and frequently even overthrown; in fact, in this area the overthrown folds or overturns are the most common kind of fold, and testify to the intensity of the folding action.

This folding took place very slowly, so slowly that erosion may have almost kept pace with the uplifting beds. Besides the two kinds of anticlines, the normal anticline and the overturned anticline, the region is full of faults and crushed and broken structure;

so that, with the scarcity of outcrops, it is impossible to follow or trace the anticlines with accuracy, though in many cases, by means of their effect upon the topography, they may be followed with some degree of accuracy for long distances.

These folds have a nearly east and west trend, and are crossed in traversing the region in a north and south line.

On one such line there are as many as thirty-nine anticlines in a distance of twenty-four miles. Many of these anticlines cannot be found at more than one place, others may be traced for a score or two of miles. Normal anticlines sometimes merge into overturns.

A Period of Erosion and Sinking.—As already suggested, the erosion during the period of active folding may have been considerable; so that it is probable that at no time did the elevations over the area at all approach the altitude that a restoration of the eroded strata would make. At last the time came when erosion exceeded elevation and probably sinking took place over the whole region. This resulted in the formation of a base level of erosion.[1] That is, the land level in its lowest part was so near sea level that subaërial erosion was entirely expended in wearing down the elevations, and as the sinking proceeded and the oceanic waters advanced, wave action completed the leveling process. Evidences of this old sea bottom are abundant; only the narrow remnant of flat country fringing the south edge of the area need be mentioned here.

The exact extent of this inundation is unknown, but there are reasons for believing that it extended north of the region under consideration.[2] During this inundation the Cretaceous beds, of which a remnant is still found lying unconformably on the southern edge of the region, were laid down.

All details of the record of events during Cretaceous times are lost in the region to be studied, the evidence only permitting us to say, that some time previous to the Cretaceous the area was reduced to a base level, after which the Cretaceous beds were laid down. The region may have subsequently been subjected to several periods of erosion and deposition.

Following some or all of these periods of deposition came elevation, with the centre of elevation in the neighborhood of the Rich

[1] Dutton, *Tertiary History of the Grand Cañon District*, p. 76.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 220.

mountain. This, then, became the centre of drainage for southwestern Arkansas and the adjacent part of the Indian Territory, the streams flowing away in every direction over the newly exposed beds of Cretaceous material. A glance at a map of Arkansas and Indian Territory will show that the streams thus started have persisted to the present.

After these streams had cut through the overlying Cretaceous they struck the hard layers of Carboniferous sandstone, and slowly cut their channels down through the harder layers standing across their path. In the course of time the Cretaceous beds were completely removed from the region north of the existing Cretaceous border. The period ends with the deposit of Tertiary beds over the eastern end.[1]

A Recent Subsidence.—There has been a recent subsidence of the region which probably did not submerge the novaculite mountains to the north, but brought them in range of wave action. The hard novaculites tend to disintegrate into blocks rather than fine material, and as the waters receded, these blocks of novaculite with others of sandstone were rounded by wave action, broken up and the whole scattered as a great gravel bed, in places at least one hundred and fifty feet deep and probably much more, over the area and far to the south. This subsidence is thought to have taken place in post-Tertiary time. The greater portion of the novaculite and sandstone drift laid down in the preceding period has been removed recently, leaving only a narrow strip undisturbed on the southern edge, and in patches all over the region, where the larger boulders have resisted erosion.

III. Original Stratigraphy.

In this chapter will be considered the character, thickness and manner of deposition of the Paleozoic beds. It will be practically a consideration of the first period in the history of the region, as outlined in the preceding chapter.

Petrology.

Rocks of the Novaculite Series.[2]—The divisions of the rocks of the novaculite series made by Mr. Griswold will be followed. These rocks he divides as follows:

[1] *Geol. Surv. of Ark.*, An. Rep. for 1892, Vol. ii.
[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 122.

I. Ouachita stones: those novaculites which "originally contained a large percentage of lime."

II. True novaculites: these are the characteristic rocks of the mountains of the Ouachita system. They are believed by Mr. Griswold to be mechanical sediments. They are nearly pure silica, though "originally containing a small percentage of lime." In color they are white, black, red, yellow, gray and mottled.

III. Silicious shales, containing "little lime, but with more abundant clay."

IV. Sandstones and quartzites.

V. Chert.

The finding of a large number of species of graptolites in the silicious shales has shown that the novaculites are of Lower Silurian age and probably belong to the lower part of the Trenton.

Petrology of the Carboniferous Area.

Sandstones.—Probably nine-tenths of the Carboniferous beds are sandstones. Mr. Griswold has described a microscopic slide of sandstone from Grindstone Ridge in 6 S., 20 W., which gives the characteristics of a typical sandstone of the region.[1]

"This stone is coarse grained, light gray in color." It contains only a small amount of "iron and earthy material."

"There are rounded as well as angular quartz grains, and a few grains of decomposed feldspar are present. The quartz grains appear to have been eroded against and even into one another; many of them exhibit lines or striations, which probably result from pressure. Since these lines are not continuous from one pebble to another, and have apparently no relation to each other, they must have been produced in some manner on the original grain and in the original rock. Some of the quartz grains show secondary silica added to the original grain to form crystal faces as described by Irving in his article on quartzites.[2] One quartz fragment is filled with very fine needles which may be rutile."

The specimen is a trifle finer grained than the average sandstone. The sandstones naturally grade into each other, but certain artificial divisions may be made for convenience. These rocks have not been, as a rule, identified with any definite position in the strata.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 141.

[2] *Fifth Annual Report of the United States Geological Survey*, pp. 221–223.

(*a*) The sandstone most commonly met with is a soft, olive green sandstone, upon exposure decomposing rapidly into sand. Except when freshly exposed this rock is seldom seen in its massive state; but its soft edges are constantly found in the roads and over the more level territory. Probably this sandstone differs from the next only in lacking iron.

(*b*) The bulk of exposures of a massive character are of a ferruginous sandstone, usually a dark red or brown. In this, exposure to the air oxidizes the iron, which forms a cement and makes the exterior much more impervious. Frequently the brown color penetrates only a short distance, and the interior is a steel gray or light green in color.

(*c*) In a few localities a very white sandstone was found. Surface exposures are usually quite soft. Where fresh, as was found in digging a well on the farm of Mr. Tom Hodges in 6 S., 19 W., section 4, it is exceedingly tough, making digging very slow and laborious. A few months' exposure of the rock is sufficient to render it very friable and mealy. In places it shows slight traces of pyrite.

(*d*) Of frequent occurrence are varieties of finely laminated sandstones verging into shaly sandstones or arenaceous shales. These are usually dark colored or black, and, where the layers are not too thin, are said to make good stones for chimneys and fireplaces. They often occur in layers not more than a quarter of an inch thick, and are frequently found interbedded with shale. There are many intermediate forms, and varieties differing both in hardness and color, but they are not worthy of special mention.

Shales.—The presence of the shales is usually indicated only by the topography or by their being struck in digging wells. Single beds are seldom over fifty feet thick, though in a few places it has a thickness of from one hundred to three hundred feet, and in one place on the Cossatot, in 6 S., 30 W., section 19, it appears to have a thickness of six hundred feet. In one place a thickness of twenty feet was seen to thin out within two hundred to three hundred yards.

It varies in lithographic characters very like the shale of other regions; sometimes it breaks up upon exposure into long, slender, needle-like fragments; sometimes it breaks up into thin laminæ or flakes; at other times it is traversed by joints that cause it to break into angular blocks, and these all weather rapidly into clay. In color they are black, lead colored, cream colored, and reddish.

Conglomerate.—First found in the Chalybeate mountain where cut by the Caddo, and later in a large number of places over the region, occurs a coarse grit or fine conglomerate. In places this forms a distinct bed eighteen inches or a few feet thick, but oftener it mingles in indistinct layers with the sandstones in a bed from fifty to one hundred feet in thickness, and varies all the way from a conglomerate to the fine-grained sandstone with which it is associated. It consists of small, rounded grains of milky quartz, none of which are more than a quarter of an inch in diameter, cemented by fine sand and iron.

Novaculite.—Reference is here made to a layer of novaculite from two to six inches thick which is found well scattered over the region. Considering the thinness of the layer, its persistence is remarkable, as it was found from range 22 W. to the territory line, and from the novaculite mountains to township 7 S. Unfortunately its exact position in the series could not be determined, but it seems certain that it is above the Silurian novaculite series, yet not separated from that series by more than a few hundred feet. In only one case was it found in a creek section; it usually appears only where the layer is crossed by a road or field. At such places it can be followed by the fragments of novaculite which lie on the surface. In 5 S., 22 and 23 W., it was traced for about six miles, and at other places it wsa traced for shorter distances. It appears to be invariably associated with beds of silicious shales, the whole aggregating a thickness of about fifteen feet. In the centre occurs the characteristic novaculite from two to six inches thick. On either side of the novaculite layer is an exceedingly fine-grained silicious shale with hackly fracture, differing from novaculite in appearance only in that the grain can be made out. From this the transition may be traced through less and less silicious shales, until, at a distance of seven or eight feet on either side, it has entirely given up its silicious character and appears to be a soft, argillaceous shale, crumbling easily in the fingers, its only resemblance now to the neighboring novaculite being its color, as it still retains the peculiar drab and pink which run through the whole series.

Igneous Rock.—There appear in many places from Amity westward outcrops of rocks containing white specks a sixteenth of an inch in diameter and smaller. Other unknown ingredients appear in thin sections, but in hand specimens the white specks are a characteristic by which it can be recognized. The rock matrix

in which this white material occurs does not appear to be constant. In places it is a hard rock ringing under the hammer, with the white specks sparsely scattered through it; in other places it is a quartzite; in some places the white and yellow specks occur in a matrix of shining black rock; in others in a shaly breccia; but the matrix is generally a light green earthy material.

The proportion of white material varies from a very small per cent. to rocks in which there is little else. In many of the harder beds the soft white material weathers out, giving the rock a very cellular appearance. A typical locality is on the Amity-Hot Springs road a mile north of Amity. It here forms a bed thirty-three feet thick. It appears to be regularly bedded at every exposure found. It is well exposed in front of the Bushy Mill in 4 S., 30 W., section 7, and on the Line road, in 5 S., 32 W., section 1. It is apparently but a short distance above the novaculite series. Williams and Penrose, of the Arkansas Survey,[1] report a similar deposit in north Arkansas, which there occurs on the dividing line between the Silurian and Lower Carboniferous strata. The examinations which they have made microscopically and otherwise have led to the suggestion that this is an ash bed indicating volcanic activity somewhere at the end of the Silurian. The great variation in the matrix rocks would seem to agree with such a theory.[2]

Novaculite Breccia.—At the same locality a mile north of Amity on the Amity-Hot Springs road are found many fragments of a novaculite breccia. This is probably the same as the novaculite conglomerate referred to by Mr. Griswold, but in this case it is invariably a breccia, the fragments which here measure from an inch or two in diameter down, presenting no evidence of previous erosion.

The matrix of this breccia is usually a light green sandstone, though in a few instances it is reddish or brown. The fragments which in some cases make up the bulk of the rock, in others only scattered through the sandstone, are of novaculite and vary in color from white to red or black.

Changes in the Rocks. Sand and Clay.—The most universal change is the disintegration of the rocks into sand and clay. Pos-

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. ii, p. 375, and Vol. i, p. 128.

[2] Chemical analyses of the north Arkansas beds here referred to show that they are phosphate rocks. An example of the rock collected by Dr. Ashley was found to contain only nine per cent. of calcium phosphate.—*J. C. Branner.*

sibly related to the sandstone is a white, friable, decomposed sandstone found at a few places. A typical locality is in fields about a mile north of Amity near the Caddo Gap road. It crumbles between the fingers into a white, dust-like powder; when dry it is almost as white as chalk. This soft, decomposed condition extends to such a depth that gullies once started in it, cut deep, cañon-like ditches resembling those so common in the soft Cretaceoul marls of the region to the south.

In this sand are great numbers of concretionary ironstones, from the size of the fist up to three or four feet in diameter. These are strewn over the surface, or protrude from banks, or occasionally may be observed capping a short column of the surrounding soft material. They are usually dark brown and consist of several layers averaging half an inch thick in which the proportion of iron is quite large, surrounding a kernel of exceedingly tough gray sandstone.

Beside the ironstones, this sand is found in some places intersected by numerous joint-planes filled with thin films of iron. Quartz veins and crystals are especially abundant in localities of this nature. Through the sand are frequently little nodules of silicious shale invariably incrusted with a soft, yellow layer. These iron incrustations are formed by waters dissolving out the iron and other impurities which are again deposited in the numerous joint planes; the quartz is deposited at the same time. Quartz filling the crevices in the sandstone is abundant over most of the area. While in some places this forms only a film just thick enough to give a sparkling appearance to the rock when broken open, in others it occurs as solid veins a foot or more in thickness, which may withstand weathering better than the enclosing rocks and may appear as a low wall across the country. The smaller veins, as a rule, intersect the bedding planes at right angles or at a high angle; but many of the larger ones run parallel to the strike. There is such a case in 7 S., 32 W., sections 8 and 9, on Robinson's Fork of the Rolling Fork of Little river, where a protruding vein of quartz can be traced a mile or more in the line of strike.

Masses of interlocking crystals occur frequently, and occasionally well-formed single crystals are found. In many places in the western part of the region, the ground is completely covered with fragments of quartz, as on the "line road" in 5 S., 32 W., section 25, where the road is paved with quartz for nearly half a mile.

Superposition of the Beds.

Mr. Griswold divides the Silurian strata into two series; the novaculite series, and the beds below the novaculites. The beds below the novaculites he estimates to be 1300 feet in thickness, as far down as exposed. They consist of gray, black and yellow shales at the bottom, cherty blue limestones next above, then massive quartzose sandstones, limestones, and shales.

From several columnar sections the novaculite series appears to vary greatly in different localities. He gives, however, a generalized section, in which the order from the bottom upward is: Silicious shales, 200 feet; shale, 300 feet; novaculite, 250 feet; shale, 100 feet; novaculite, 100 feet; novaculite with silicious shale at bottom, 250 feet; novaculite breccia or conglomerate, a thin layer.

The variation in these layers may be judged by an examination of Mr. Griswold's sections.[1] Thus, as an example, the upper layer of novaculite in the Boss Allen Creek section is 500 feet thick, while in the South Fork of the Caddo section it is only 60 feet thick.

Stratification of the Carboniferous Beds.—No satisfactory columnar sections of the Carboniferous beds were obtained.

Outside of the immediate channels or banks of streams, rock exposures are rare, and when found are seldom extensive enough to give more than the dip, and the rock exposures in the stream are not usually more than a few yards long. Now and then a continuous exposure is found for several hundred feet, and in a few cases longer exposures are found; but usually between the long exposures there are so many stretches concealed, in which may be folds, or faults, or other unknown factors, that one cannot be sure of the structure. Had the beds been such as to permit identification and correlation, doubtless satisfactory sections could have been made. On Plate I are given the best general sections obtained.

Plate I, Section I.—This section was obtained on the Rolling Fork of the Little river. In 8 S., 32 W., the lower part of section 11, is a perpendicular bluff on the east bank of the Rolling Fork known as the "Buzzards' Roost." The dip at this point is about 12°, S. 18° E. Continuing up stream, sandstone is met with in bluffs and in the stream bottom almost continuously, dipping from

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.

10° to 15°, until shales are met with in the flats at the Bellah mine. Only one important break occurs, where the valley of Rabbit creek comes in. At this point may be a heavy bed of shale, and shale may exist at other points along the section, but was not seen.

From 1500 to 2000 feet of sandstone are omitted from the top of this section. The existence of faults is quite possible, but no evidence of any was found.

The position in which this section is placed relatively to the others is based upon the occurrence, in the strike of these shales and six miles to the east, of the thin beds of novaculites and shales which are known to be not far above the principal bed of novaculite.

Section II.—Section ii shows the order of rocks on Cossatot river at the gap near Pontiac post-office. The ridge crossing the Cossatot just north of Pontiac has black novaculite exposed at the centre of an anticline. The section starts from the exposure of novaculite in the gap, and runs south to where the river turns northwest half a mile below. The sandstone overlying the novaculite is poorly exposed on the south side of the anticline, but shows on the north side, and also on the south side of the ridge, east of the river. A careful section was made at this place, but as the shales and sandstones at many points in it are crushed together and broken, suggesting faults, the section is not altogether trustworthy. Omitting minor details the section is as follows:

	FEET.
Sandstone	150
Concealed	150
Heavily bedded sandstone with thin beds of shale	375
Shale with occasional beds of sandstone	325
Concealed	225
Shale and sandstone much crushed	175
Sandstone in thin beds	175
Shale and sandstone layers	50
Sandstone	25
Sandstone and quartzite	350±
Black novaculite	base
Total	2000

Plate I.

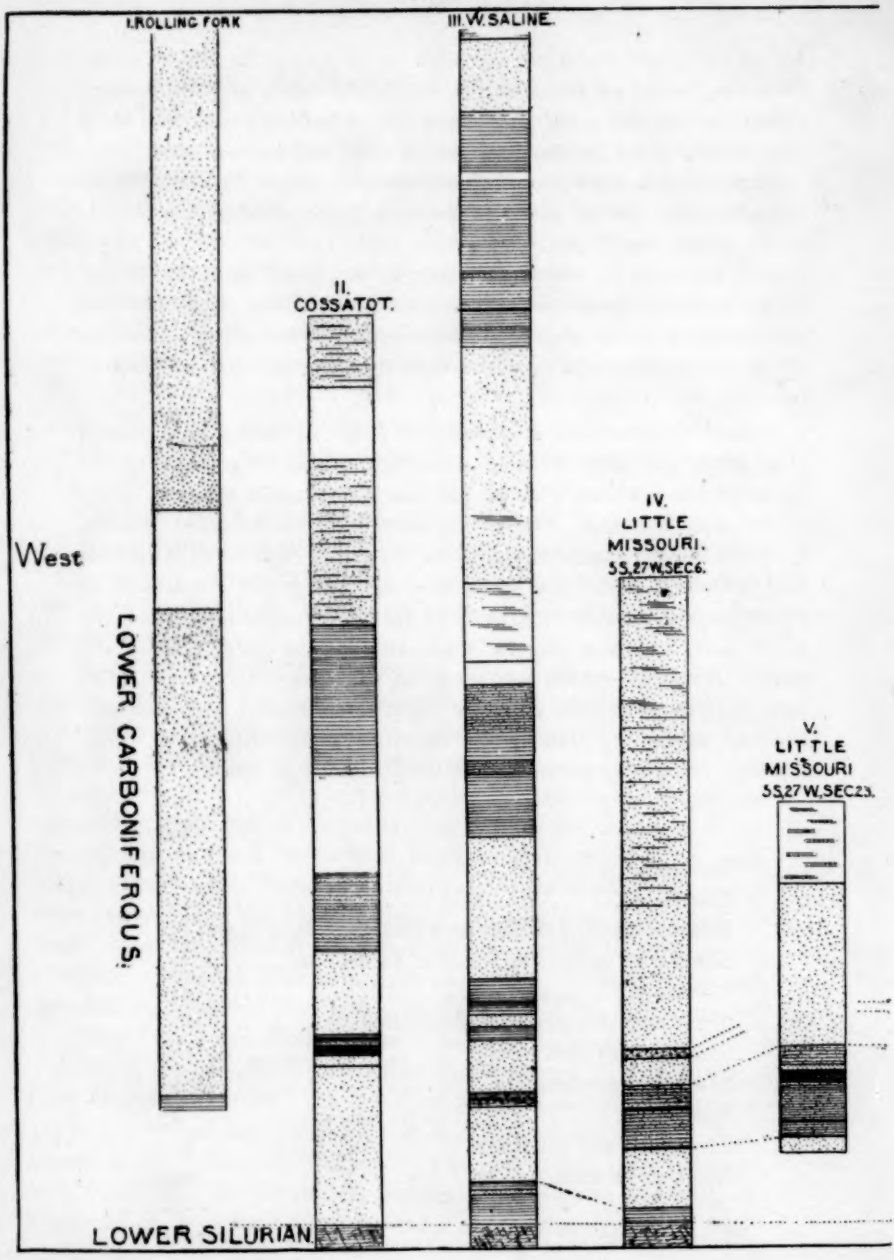
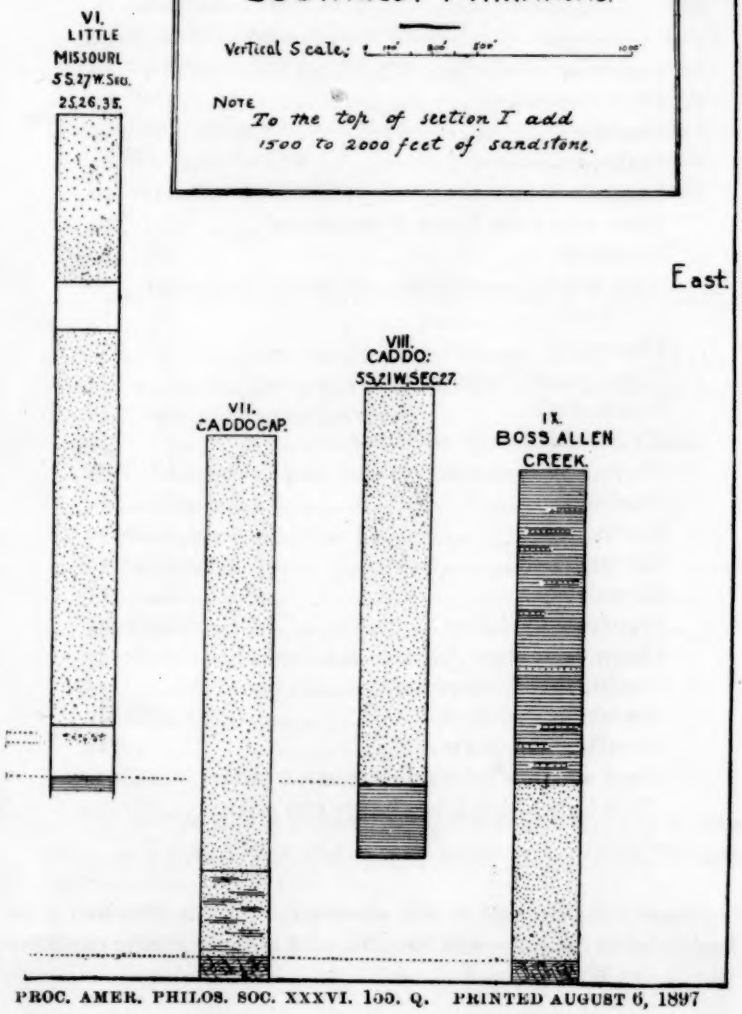

I. ROLLING FORK
II. COSSATOT.
III. W. SALINE.
IV. LITTLE MISSOURI. 5S. 27W. SEC 6.
V. LITTLE MISSOURI 5S. 27W. SEC 23.
West
LOWER CARBONIFEROUS.
LOWER SILURIAN

Plate I.

COLUMNAR SECTIONS OF THE LOWER COAL MEASURES ROCKS OF SOUTHWEST ARKANSAS.

Vertical Scale: 1 100' 200' 500' 1000'

NOTE. To the top of section I add 1500 to 2000 feet of sandstone.



PROC. AMER. PHILOS. SOC. XXXVI. 155. Q. PRINTED AUGUST 6, 1897

This section is broken at its southern end by a fault of unknown throw.

Section III.—Section iii was recorded by Prof. A. H. Purdue on the West Saline river, beginning at the gap near Moore's mill, 4 S., 28 W., section 31, and running south about a mile. This section, like the preceding, is not altogether trustworthy, for the strata are frequently nearly perpendicular and may be overthrown or faulted. The section, omitting minor details, is as follows:

	FEET.
Sandstone	10
Shale (probably)	75
Sandstone	165
Shale (probably)	165
Concealed	20
Shale with a few layers of sandstone	375
Sandstone	530
Thin bedded sandstones and shales (poor exposure)	175
Concealed	50
Thin bedded shaly sandstone	100
Green shale	50
Thin bedded shaly sandstone	30
Shale	135
Sandstone	320
Green shale	70
Sandstone	10
Green shale	25
Quartzose sandstone	35
Green shale	30
Sandstone with some shale	115
Novaculite and shale	45
Quartzose sandstone	115
Shale with few quartzitic sandstone layers	100
Thin beds of black novaculite and shale	400
Total	3195

Section IV.—Section iv was observed on Little Missouri river beginning at the gap where the river cuts through Prairie mountain in 5 S., 27 W., section 6.

The anticline at this gap shows nicely; the section as given on Pl. i begins with the top of the black novaculite and shale. The section is as follows:

	FEET.
Sandstone with some shale (poor exposure)	300
Sandstone with thin layers of shale.....	400
Sandstone.....	365
Grit or conglomerate	25
Sandstone.....	60
Shaly sandstone in thin layers.....	140
Sandstone, soft yellow where weathered	130
Shale.....	30
Black novaculite and shale.....	400
White novaculite.....	400
Shale and sandstone.....	base
Total.....	2450

The thickness of the Carboniferous in this section is about 1600 feet.

Section V.—Section v is on Little Missouri river, in 5 S., 27 W., section 23, on the north and south stretch in the middle of the section. The section obtained was:

	FEET.
Sandstone, all that showed (poor exposure).....	185
Sandstone.....	370
Shaly sandstone thin bedded.	40
Sandstone.....	10
Shale.....	15
Sandstone.....	5
Shaly sandstone thin bedded, with some hard sandstone.....	130
Sandstone.....	30
Total.....	785

This section is well exposed along the river bank, and is accurate as far as it goes. The dip at the north end is high, but quickly becomes low.

Section VI.—Section vi is on Little Missouri river, beginning at Pine mountain, in 5 S., 27 W., section 26, and running south to

where the river turns east and northeast. The dip is low, from 10° to 20°. At the north foot of Pine mountain a bed of shale is exposed, then for a short distance it is concealed beneath broken sandstone blocks. Near the top of the mountain on the north side in this area of no outcrops were found many pieces of grit or conglomerate, indicating its presence there in place. Massive layers of sandstone, twenty to forty feet thick, form the top and south slope, dipping 20° south. For most of the rest of the distance the sandstone is exposed almost continuously in low, perpendicular cliffs, the dip being very low. This is thought to be a single outcrop to the centre of section 31 in the next township east. This cross-section and the preceding are separated only by a short stretch in which there are no exposures. The dip is the same, and it is possible that the two are part of one section; many things, however, point to its being a repetition of the preceding section, and the topography also is suggestive of a fault between the two.

The section gives:

	FEET.
Sandstone	400
Concealed	100
Sandstone	900
Concealed	115
Shale	30
Total	1545

Section VII.—Section vii, at Caddo Gap, is quoted from Mr. Griswold.[1]

It is as follows:

	FEET.
Sandstone	980
Sandstone with some shale	200
Silurian novaculites, etc	base
Thickness of the Carboniferous beds	1180

Section VIII.—Section viii is on Caddo river, in 5 S., 21 W., section 27. A long stretch of low dip (from 5° to 10°) with continuous outcrops gives this section:

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.

	FEET.
Sandstone	900
Shale	75
Black shale with fossils	100
Total	1175

There is evidence of much shale below the bottom of this section.

Section IX.—Section ix is on Boss Allen creek, in 3 S., 18 W.; it was obtained by Mr. Griswold.[1]

	FEET.
Shale with some sandstone	700
Sandstone	400
Novaculites, etc. (Silurian)	
Thickness of the Carboniferous	1100

Besides these sections, mention might be made of a continuous outcrop of perpendicular sandstone with some thin layers of shale, which forms the east bank of the Little Missouri in 6 S., 26 W., section 25. In this outcrop the beds exposed have apparently a thickness of 1500 feet.

On the Cossatot, in 6 S., 30 W., section 19, is a continuous exposure of arenaceous shale or shaly sandstone giving a thickness of 600 feet, which is much greater than the exposure of the same rock elsewhere.

On the Cossatot, in 5 S., 30 W., section 17, is a fine exposure of sandstone which at this point crosses the river in high massive ledges from ten to twenty feet thick and dipping north 30°. The river cuts through these ledges forming a series of cascades known as the Falls of the Cossatot. The thickness is about 800 feet.

Stratigraphic Position of the Beds.

(*a*) *The Novaculite Breccia.*—The novaculite breccia was only met with in quantity a mile north of Amity (see p. 232). It appears there following the strike of the rocks. Mr. Griswold reports[2] a novaculite conglomerate or breccia occurring just at the top of the novaculite series. This is thought by Dr. Branner to be the top of the lower Silurian strata.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.
[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. ii, p. 300.

(*b*) *Igneous Rock.*—This is well shown at the same locality as the breccia, and there appears to occupy about the same horizon. It was found at about a score of places west of the Cossatot, these being always, where the structure was known, just at the axes of anticlines; and, as in many places among the novaculite mountains, it is found very close to the novaculite, it may be safely assumed that it is but a short distance above the novaculite, and may well be taken, as has been suggested, as the dividing line between the Silurian and the Carboniferous.[1]

(*c*) *The Thin Bed of Novaculite and Associated Shales.*—Notwithstanding the large number of places at which this bed was met with, it only appears in one of the columnar sections. In the Saline section it appears not much more than one hundred and fifty feet above the top of the black novaculite and shales. It is usually exposed near anticlines; in many cases, exposures are found on each side of the anticline. This would place it low in the series, but the distance between the exposures, frequently a quarter of a mile, and the distance of exposures from the thick-bedded novaculite, where exposed in the fold over a novaculite ridge, suggest that generally this thin layer of novaculite is several hundred feet above the black novaculite. Considering the thickness of the bed, from three to ten inches, it is remarkably persistent; the most southern exposures in township 7 S. appearing practically identical in thickness and character with the exposures close to the novaculite ridges.

In the Saline section it is in a thick bed of sandstone. In a fine exposure on the Caddo in 5 S., 23 W., section 21, northwest corner, there are thick beds of shale above and below it, and it shows this difference in many exposures.

Whether or not it is above or below the lowest of the beds which, by their fossils, are known to be Carboniferous, is not known. If it is below and belongs to the Silurian novaculites, we must acknowledge the existence of belts of Silurian strata all through the area. If it is above, as seems possible, we have the remarkable case of unusual conditions which dominate in one age returning after a long interval in a much later age, not in a single locality, but widespread though of short duration.

(*d*) *The Grit or Fine Conglomerate.*—In Pl. i, Sec. iv, on the

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. i, p. 128, and Vol. ii, p. 375. For doubt regarding the igneous nature of some of these beds see footnote on p. 232.

Little Missouri, the grit appears about four hundred feet above the black novaculite. In the Cossatot section it appears east of the river just below the shales and not more than six hundred feet above the black novaculite. This, together with the fact that it is usually found elsewhere close to the anticlines, indicate that it is not far above the novaculite, probably within a few hundred feet. Its relation to surrounding beds varies greatly: in places it is just below thick beds of shale, in other places it is just below thick beds of sandstone; hardly any two exposures agreeing, so that while lithologically it is very similar wherever found, it is quite possible that the different exposures are only local in extent and occur in different horizons. In several places, however, the grit has been traced in more or less continuous exposures for several miles.

A General Section.—Could we construct a general section it would be somewhat as follows:

5. Sandstones forming top of exposed beds and having a thickness at one place of four thousand feet or more.

4. A variable set of beds of shale and sandstone measuring at least several hundred feet in which occur,

(*a*) A bed of beds or grit.

(*b*) A thin bed of novaculite and silicious shales.

3. A bed probably of igneous origin, thirty-three feet.

2. A thin bed of novaculite breccia.

1. Silurian novaculites, shales and sandstones.

IV. Fossils and Age of the Strata.

Caddo River Locality.—The first and most promising locality at which plant remains were found is in 5 S., 21 W., on the tongue of land just east of the mouth of Point Cedar creek. There is here a good exposure of black, carbonaceous shale having a peculiar hackley fracture. This contains a great many minute fragments of plants. Only a few are large enough to show any characters; of these the most common are long stems showing no branches, but ribbed longitudinally. These stems average a quarter of an inch in width by several inches in length. They are the most common fossils found in the area. They occur at several places, but at none of these places were any obtained which would permit a closer identification than that they were the stems of some plant. There

was also found at this point a fragment of a larger stem showing leaf scars. The original material of the specimen has been carbonized. The specimen was not identified. Small round stems are also found at this place, but though showing some structure under the microscope, they were not identified. This and the next were the only localities found which promise fossils of value on further exploration.

Bluff Mountain Locality.—Sparsely scattered through the shale and sandstones forming the northern part of the bluff on the west side of Antoine creek at Bluff mountain in 7 S., 23 W., section 34, were found many fragments of stems similar to those mentioned above.

Suck Creek Locality.—The same kind of stems were also found in a loose block, well up on the north bank of Suck creek in 7 S., 23 W., section 30, at the bend where the creek changes from an east to a south course.

Chalybeate Mountain Locality.—Where the Caddo Gap road crosses the Chalybeate mountain in 7 S., 24 W., section 1, the rocks exposed in working the road near the top show traces of plant life, but nothing was found that could be identified.

Little Missouri Locality near Murfreesboro.—On the Little Missouri river in 8 S., 25 W., section 6, a few of the stems common to this region were found in an argillaceous sandstone.

Little Missouri Locality near Pine Mountain.—Plant fragments like those mentioned above were also found on the Little Missouri in 5 S., 27 W., section 23, in the shales in the bend of the river half a mile north of where Pine mountain strikes the river.

Little Missouri Locality near Gap.—A short distance south of the Gap in 5 S., 27 W., section 5, at the south end of the layers of shaly sandstone, the shale or sandstone is full of carbonaceous streaks and patches, which prove to be remains of stems of plants very poorly preserved. The impression of a stem with a thorn was found at this point. The stratigraphic position of this locality is shown on Pl. i, Sec. iv, the specimens are from the top of the arenaceous shale just below the grit shown, and only about 300 feet above the black novaculite and shale.

Star-of-the-West Locality.—On the south bank of the creek (just south of Star-of-the-West), at the foot of the hill, was found a section of a stem an inch and a half in diameter which is probably a Calamites. This was found loose on the hillside and probably came from the shales which form the bank at this point.

Panther Bluff Locality.—At Panther Bluff on the Saline river in 6 S., 29 W., section 33, shales are interbedded with sandstones, and in these shales a fragment showing the peculiar ribbing and jointing of the Calamites was found. This was the only specimen found of which the genus could be determined with certainty.

Saline River Locality near Antimony Cave.—Prof. Purdue found fragments of plants on the Saline at the bend just above Arsenic Cave in 7 S., 29 W., section 21. They are too poorly preserved for identification.

Animal Remains.

Some fragments of crinoid stems and a few bryozoans, were found in a loose quartzite boulder near the crossing of Antoine creek by the Old Military road (8 S., 23 W., section 24). The only other evidences of animal life found were what are thought to be tracks of worms or crustaceans. These were found at two localities in 5 S., 23 W., section 31, on the Amity-Kirby road, a quarter of a mile west of the crossing of the North Fork of Antoine creek, and also in section 14, on a knoll southeast of Sugar Loaf mountain.

Geologic Age of the Rocks.

The age of the Silurian strata has been determined by means of the numerous graptolites found in the shales associated with the novaculite. The shales containing these graptolites have been correlated with the Norman's Kill beds of New York, and are referred to the lower portion of the Trenton series.[1] These fossils fix the age of the Silurian beds.

Of the fossils found in the overlying Lower Coal Measures rocks only three have any diagnostic value: the two specimens of Calamites and the stem found on the Caddo, which shows the leaf scars. These plant remains are probably of Carboniferous age. The stems and other fragments often found are of no value, as they might occur anywhere from the Cambrian up, but from their association on the Caddo with the stems believed to be Carboniferous, it has been assumed that they belong to the Carboniferous, and that all beds in this particular region in which they occur are Carboniferous.

Upon the above grounds it has been thought safe to refer the strata above the novaculites to the Carboniferous age. The grits which cap the mountains along the northern face of the Boston

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 418, *et seq.*

mountains gradually dip south and disappear under the heavy beds of the Coal Measures which fill the syncline of the Arkansas river basin. If these beds persist to the south they should appear again on the north side of the Ouachita uplift, and should disappear with a south dip on the south side of the uplift. The State Geologist is of the opinion that the grits described in this area represent the southern extension of the Millstone Grit of north Arkansas. The two are identical in appearance, except that the rocks of the southern area are never as coarse grained as some of that to the north.

The Millstone Grits of north Arkansas are at the bottom of the Coal Measures; so that if the grits south of the Ouachita uplift be correlated with those of north Arkansas we must consider that we have strata referable to both the Coal Measures and Lower Carboniferous or Mississippian series.

Without regard to time, it seems highly probable that the strata south of the Ouachita uplift were originally continuous with those just north of it. No direct proof of this has been found, nor has anything been found that conflicts with this theory.

Previous Correlations.

Thomas Nuttall, who was in this part of Arkansas in 1819, published many observations on the geology, but he found no fossils in these lower sandstones and made no attempt to correlate them.[1]

In 1834, G. W. Featherstonhaugh, U. S. Geologist, made an examination of the elevated country between the Missouri and Red rivers.[2]

He passed along the eastern edge of our region and down the Ouachita river. The ferruginous sandstones he referred to the Old Red Sandstone (Devonian) of England, which he thought to rest upon the grauwacke, the grauwacke being the shales and shaly sandstones at the bottom of the series.

He failed to recognize the intimate relation between the shale and sandstone or the folded condition of the strata. He was originally

[1] "Observations on the Geological Structure of the Valley of the Mississippi," by Thomas Nuttall, *Jour. Acad. Nat. Sci. of Philadelphia*, Vol. ii, Pt. i. Phila., 1821, pp. 48–52.

[2] *Geological Report on an Examination made in 1834 of the Elevated Country between the Missouri and Red Rivers*, by G. W. Featherstonhaugh, Washington, 1835, p. 71.

led to this classification, as Marcou [1] and others have been, by finding at Little Rock the highly contorted shales at the "Little Rock" and a few miles above, at "Big Rock," the almost horizontal sandstone strata. In 1842, Dr. W. Byrd Powell [2] questioned Featherstonhaugh's correlation with the grauwacke, but he accepted it as the best that could be given, but included the sandstones in the same classification. Dr. Englemann saw something of the region between Little Rock and Hot Springs, but he found no fossils, and the only suggestion as to correlation was that the sandstone at Little Rock was "most probably analogous to that of Lake Superior."[3]

Owen refers this region to the Millstone Grit,[4] including in the same formation the novaculites, which we now know to be Silurian.

He concludes that these beds have an immense thickness from observing sections many miles long, where the beds appear to dip steadily in one direction. This has since been shown to be due to a number of consecutive overturns.

Subsequent Observers.—Since the beginning of the present survey, several of its members have crossed this region. No fossils were found, and so, though Mr. Branner provisionally referred these beds to the Lower Carboniferous,[5] he thought it better to speak of them simply as Paleozoic.

Extent of Beds.

It can be assumed with some degree of certainty that the strata exposed over the area under discussion are continuous. This refers only to the beds as a whole, not to individual layers.

The extent to the south and east can only be conjectured, but as no thinning out could be detected, the strata may have had a considerable extent in those directions.

As will be discussed later, it has been suggested that the Ouachita

[1] *Exploration and Survey for a Railroad from the Mississippi River to the Pacific Ocean*, Vol. iii, Pt. iv, p. 122.

[2] *A Geological Report upon the Fourche Cove and its Immediate Vicinity*, by W. Byrd Powell, M.D., Little Rock, 1842.

[3] *Proc. A. A. A. S.*, v, 1851, p. 199.

[4] *Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas*, made during the years 1859–61, by D. D. Owen, Philadelphia, 1860, pp. 32, 33, 95, 110, 124.

[5] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 262.

uplift is a remnant of a westward extension of the Appalachian chain. As this view presents certain difficulties, there has also been advanced the theory that that westward extension, if it existed, was to the south, possibly crossing the northern part of Louisiana. In such a case these beds may have been continuous with, though varying from, the Carboniferous exposures on the west of the Appalachians.

To the west the same beds run into the Indian Territory, and the Carboniferous is found as far west as the 100th meridian and in Texas as far south as the thirty-first parallel.

To the north the strata are thought to have been originally continuous with the strata just north of the Ouachita uplift.

Several attempts to prove this continuity were made, but without much success, though nothing to the contrary was found.

Direction and Conditions of Depositions.

Mr. Griswold, from his study of the novaculite area, came to the conclusion that the sediments with which he had to deal came from the south.[1] This was largely based upon the fact that the sandstones overlying the novaculite on the south are largely represented on the north by shales. Apparently the same fact is also to be observed in our area. This is shown by the difference in the topography: almost no shale being met with in the southern part of the region, and east and west valleys of any breadth are uncommon, while as the novaculite mountains are approached there are broad valleys with frequent exposures of shale. It was at first thought that this might be due to the strata as a whole having a slight south dip, so that the shales, which are low in the series, were not as fully exposed, but, as will be shown later, the proof is to the contrary. There also appears to be more shale exposed over the eastern part than over the western; but this is not marked enough to make one feel sure but that greater erosion may have had something to do with the difference.

V. General View of Structure After Folding.

In Fig. 1 is given a generalized section across the State in a north-south line through range 30 W.

[1] *Geol. Survey of Ark.*, Rep. for 1890, Vol. iii, p. 193.

FIG. 1.—North-south section across the State of Arkansas through range 30 W.

This section has been compiled from observations by members of the survey.[1]

It shows a monocline on the north, a syncline in the centre, an anticline south of that, and a nonconformity at the southern limit.

The gradual change from practically horizontal strata on the north to highly folded on the south is also shown.

At the north Silurian strata are exposed, but on going south these gradually sink beneath Carboniferous deposits, to appear again in the great anticline of the Ouachita uplift. On disappearing again they continue but a short distance below the surface, until they and the overlying Carboniferous beds are covered by the gently dipping Cretaceous strata.

The section is given to show the relation of the area under discussion to the general section of western Arkansas. The line on which the section is made crosses the Ouachita uplift not far from its western nose, so that the Silurian outcrop is very small compared with what it would be on a north-south line further east, and likewise the Carboniferous outcrop south of the Silurian would be narrower in a section further east.

Historical.

None of the early writers on the geology of Arkansas seem to have made any attempt to work out the structure of the Ouachita uplift, or of the region immediately south of it.

Comstock.[2]—The first attempt to give system to the folds was made by Dr. Theo. B. Comstock

[1] Winslow, "Geotectonic and Physiographic Geology of Western Arkansas," *Bulletin Geological Society of America*, Vol. ii, pp. 225–242, Fig. 1; *Geol. Surv. of Ark.*, Rep. for 1891, Vol. iv, sections; *Geol. Surv. of Ark.*, Rep. for 1890, Vol. iii, section on Mt. Ida sheet; *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, sections p. 126.

[2] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. i, pp. 130–166.

North-South Sections in the Paleozoic Region South of the Novaculite Area.

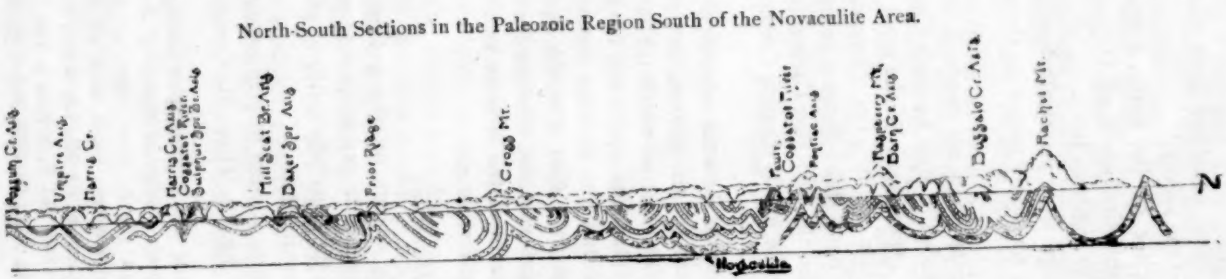


FIG. 1.—Section on Antoine Creek.

Horizontal scale: 1 inch = 2 miles. Vertical scale: 1 inch = 3000 feet.

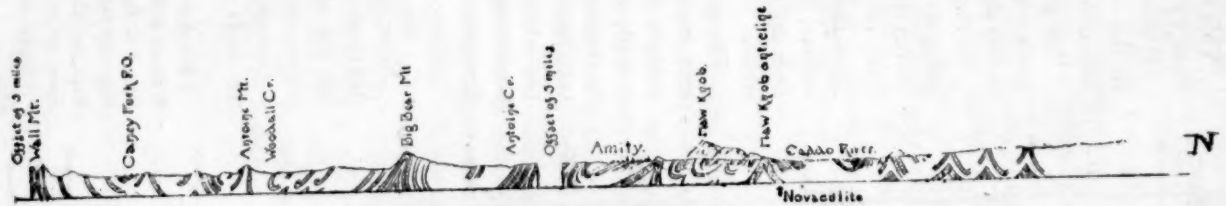


FIG. 2.—Section on Cossatot River and Brushy Fork.

Plate II.

FIG. 1.—Section on Antoine Creek (continued).

FIG. 2.—Section on Cossatot River and Brushy Fork (continued).

in 1887. He worked only in the western part and mapped out twenty folds and faults having a strike of N. 63° E., and connected with a similar number near Hot Springs.

That he should have found a uniform strike of N. 63° E. is difficult to explain, for the strike is extremely variable, seldom being the same in strata 100 yards apart. At most of the localities cited by him the strike lacks from 10° to 40° of being N. 63° E. The fact that so many ridges run "transverse to all geologic structural lines," he disposes of by introducing "some very powerful cause of greater moment than the twenty folds and faults which cut across the tract." But as a matter of fact these ridges are strictly conformable to the structure. The evidences of faulting which he found are all referable to the simple effects of erosion upon tilted beds, some of which are much harder than others. Considering the shortness of the time spent in the region and the obscurity of the structure, even at the best, and that outside of the river channels good exposures are rare and generally unsatisfactory, and that in the first of his field work, where the structure was more evident, the ridges have a trend of northeast-southwest, it is readily seen how he fell into error.

Subsequent Observers.—From that time until the work herein reported was taken up all the work done was such observations as different members of the survey made in traversing the region. These observations soon disclosed the errors of previous work, but did not reveal the number or closeness of the axes.

The Cross Sections.

An idea of the folding can be gained from the north-south sections on Pl. II (see p. 250).

The Antoine Section.—Fig. 1 gives a section through the centre of range 23 W. The part in township 6 S. is offset five miles, to a north-south line through Caney Fork P. O. The section in 7 and 8 S. is made along Antoine creek. Its striking general feature is the prevalence of south dips and overturned folds except at the ends. The first attempt to make this section gave only one doubtful north dip in shale. Further, the closeness of folding does not diminish to the south. The exposures are mostly sandstone, though in many cases the presence of shale can be inferred from the topography. In the segment through Caney Fork P. O. the topography is controlled by the structure, this being almost the only locality in the whole area

where distinct anticlinal ridges with synclinal valleys between were found.

The Cossatot Section.—Fig. 2, Plate II, gives a section up the Cossatot river to the mouth of Brushy Fork, and thence up Brushy Fork to the north line of 4 S. The dip is north with many overthrows to the south. The southern end is not as closely folded as would be the case further east. The presence of one or more layers of shale or shaly sandstone has assisted materially in determining the structure. The exposures along the Cossatot are more numerous and the structure ascertainable with more certainty than on the Antoine. The novaculite is not exposed except at the extreme northern end of the section; but at many places it cannot be far from the surface, as it comes to the surface but a short distance east in Rachel and Raspberry mountains, and a short distance west in Cross mountain.

Direction and General Character of the Folds.

Eastern Sheet.—The structure of the eastern portion of the Lower Coal Measures area is obscure, and, as the map shows, but little understood.

This is due to three causes. Principally the prevalence of overturns; next, the fact that erosion has progressed until the streams are comparatively slow, with banks neither high nor precipitous, thus presenting few fresh exposures of rock; and again, the wide distribution of water-worn material which conceals everything.

From these causes the number of exposures found giving a dip and strike would average less than one to the square mile; in many townships they are as low as one in four to eight square miles. If a complete structural map of the region could be made it would probably show many more folds than are here indicated. At the eastern end of the map the anticlines and synclines all run nearly due west. In range 21 W. they all bend south, running 12° to 15° south of west. The Suck creek anticline and Bell's creek anticline are exceptions to this rule.

West of range 23 the folds in township 4 S. regain their due west course, the folds to the south maintaining the direction of 12° to 15° south of west. Of the anticlines shown, about one-half are overturns. Indications suggesting the existence of many other overturns were found, but they were not well enough marked to warrant their insertion.

PROC. AMER. PHILOS. SOC. XXXVI. 155. B. PRINTED AUGUST 6, 1897.

The Western Sheet.—The western half of the area offered somewhat better facilities for working out the structure, due principally to the existence of four large streams running across the folds from north to south. These streams are rapid, and frequently they cut their way through the ridges in deep, steep-banked gorges for long distances. Rocky cliffs seldom occur, but the shallow creek bottoms afford many exposures of rocks. Between these streams exposures are as scarce as further east.

On the other hand the topography is of much service in suggesting structure. It is through the suggestions thus given by the topography that the connections between the exposures of axes have been worked out.

In townships 3 and 4 S. the strike of the folds is east-west or a little north of west. In 5 S. the strike is nearly always about due east-west. In 6 S. the strike is a little south of west, becoming due west as the Indian Territory line is approached. In 7 S. the slightly south of west strike is maintained.

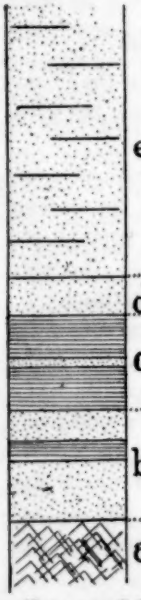


FIG. 2.—Columnar section of Paleozoic rocks south of the Ouachita mountains.

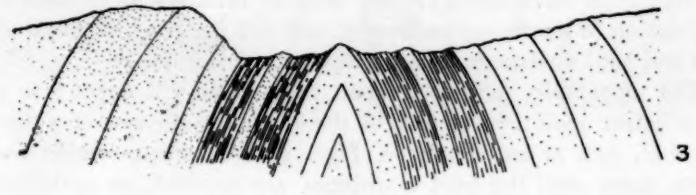
Thus it will be noticed that as the Indian Territory line is approached the fold tends to spread out like a partly opened fan. This results in the folds becoming more open toward the west. While the strata are closely folded or overturned on the Little Missouri and West Saline rivers, on the Cossatot they present more simple anticlines, and still further west, on the Rolling Fork, simple anticlines and lower dips are still more prevalent. This is especially true of the southern half of the region.

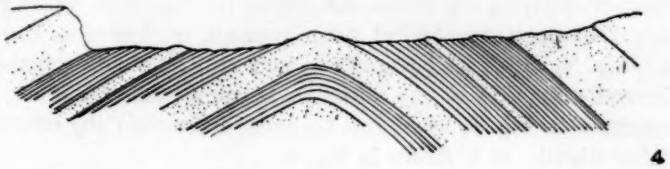
Where the dotted lines on the map suggest continuity of the axes, it is not necessarily implied that the anticlines are strictly continuous; as the complete structure, if known, might show two or more anticlines where only one is indicated, and these might be strung along in a line or be slightly out of line with the ends overlapping or running past each other.

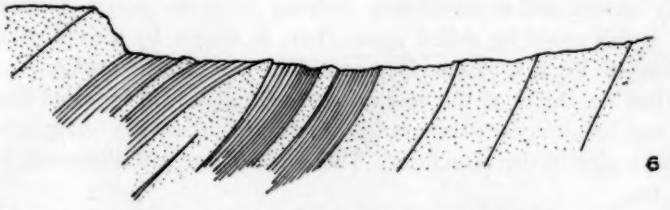
Structural Types.

As introductory to tracing out the anticlines and synclines in the next chapter, it may be well to

study briefly the effect upon the topography of such a section as here exists, when folded and the much eroded.







FIGS. 3–6.—Sections showing types of structure in the Paleozoic region of southwest Arkansas.

Let Fig. 2 be a very generalized columnar section, in which (*a*) represents the Silurian novaculites, (*b*) the sandstone immediately overlying the novaculites, (*c*) the variable thickness of sandstones and shales, (*d*) massive sandstones, and (*e*) the great thickness of soft and hard sandstones forming most of the section.

The topography developed upon these beds will depend to a great extent upon the character of the folds. In the case of a simple fold, such as are shown on Figs. 3 and 4, where erosion has eaten down until the hard sandstones are exposed, an anticlinal ridge will follow the axis with a valley on either side. Figs. 3 and 4 show the effect of the dip upon the width and character of the valleys. As a rule it is found that, of the ridges formed by the sandstones overlying the shales, the one on the side from which the principal drainage comes is cut down so as not to present an abrupt face. Fig. 5, shows the effect of two such anticlines close together.

Generally one side of the anticline is steeper than the other, as is suggested in Fig. 8, when this becomes overturned the effect is modified slightly, as is shown in Fig. 6.

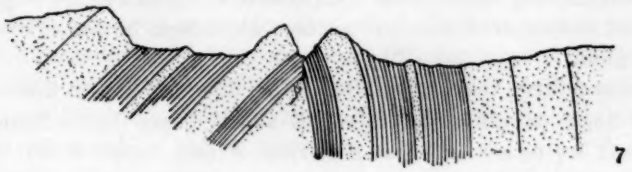
Where shale underlies the sandstone of the anticlinal axis, in time this anticline becomes breached (Fig. 7), and the topography resembles that of which the Wall mountain (Figs. 27 and 28) is an excellent example.

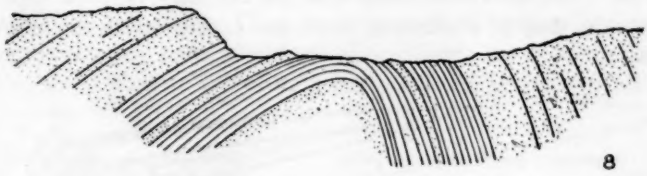
If erosion has not cut down to the underlying sandstone, the result will be the same, except that the anticlinal ridge is omitted and the valley will be narrower, possibly very much narrower. Such an anticline (Fig. 8), is difficult to locate accurately. This is a common type; it is illustrated by the Prairie Bayou anticline (Fig. 16).

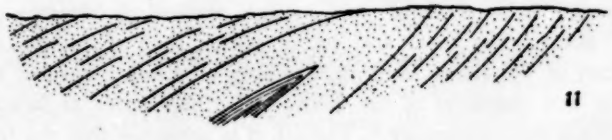
Overturns of the kind shown in Fig. 9, are very difficult to recognize; the mere presence of the shaly layers is frequently the only suggestion of their presence. If the shaly layers were as surely located and as completely isolated as in the general section, Fig. 2, this could be relied upon; but, as shown by the columnar sections of Pl. I, it cannot be taken alone as a sure indication.

When the shales of the section are somewhat deeper seated they may not be brought within range of erosion; then the topography gives no clue to the structure. These conditions are illustrated by Fig. 10.

If an overturn occurs under such conditions as those suggested in Fig. 11, unless an exposure is found at the axis, it will generally pass unnoticed.







FIGS. 7–11.—Sections showing types of structure and topography.

In each of these cases, while erosion is the apparent agency, the real determining factor is the comparative elevations of the original surfaces as compared with the average elevations of the surrounding region.

The anticlines may vary in height at different points, however, and a single anticline may represent almost every feature figured; for, as it begins low and gradually rises, it may expose at first only the upper sandstones, then the shales, then anticlinal ridges due to sandstones in or under the shales, as shown diagrammatically in Fig. 12. The anticlines which near the end may have low dips on either side, may be overturned near the centre or for much of its course.

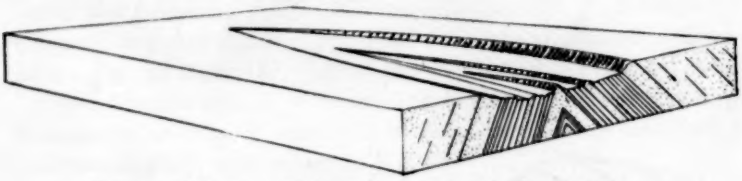


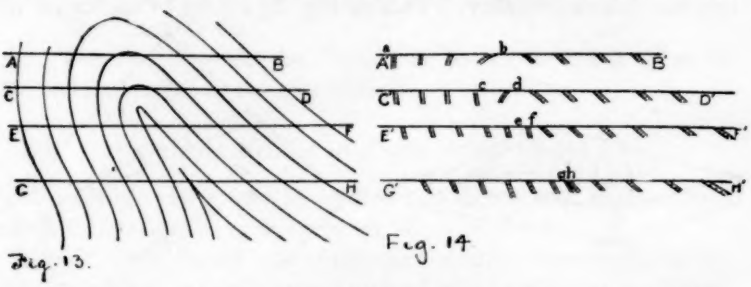
FIG. 12.—Diagram of topography at the end of an anticline.

Under the circumstances represented in Fig. 12 it would seem an easy matter to locate and accurately define the anticlines and synclines. As a matter of fact, almost no such evident structural topography is met with in the region under consideration.

While the topography is largely concordant with the structure, many disturbing elements enter which vitiate any conclusions that may be based upon topography alone. On account of causes to be spoken of later, the main drainage systems of the area are only slightly controlled by structure, their general trend being oblique or transverse to the strike of the folds. This results in a double series of valleys cutting each other at all angles; and through the same causes the main divides are also transverse to the structure and on these for a width of from half a mile to several miles the topography is usually not well enough marked to indicate structure. Many other local and minor causes, such as change in the character of the rocks, faulting, crushing of strata, constant variation in the character of the folds, and others enter as factors to complicate the topography. Though it is probable that the topography, if worked out in detail, would be found to be closely governed by the structure, modified by the factors mentioned,

yet, when it is considered that, on account of the density of the forest, it is but rarely that the "lay of the land" can be made out for more than one or two hundred yards from the course pursued, it will be understood why, in a rapid reconnaissance like that undertaken, but little more than suggestions could be obtained from the topography. For these reasons the structure has, in no case, been assumed from the topography alone.

Overturns.—Overturns are a common feature of the area. In Fig. 13 is a simple overturn, and on the right side (Fig. 14) are shown the corresponding dips of beds at surfaces of different levels as AB, CD, EF, GH. Thus, in the case of A′B′ the axis is readily recognized; but remembering that no correlation of beds can be made, the section at that point would naturally be interpreted as an



FIGS. 13, 14.—Diagrams illustrating the structures shown by eroding an overturn to different depths.

anticline at *b* and a syncline at *a*. Such overturns are liable to lead to a confusion which can only be cleared up by careful detailed work.

In C′D′ and E′F′, the structure is the same, but is somewhat modified.

Most of the overturns found have been eroded so as to give exposures between those of C′D′ and E′F′. Sometimes there is a marked change in the dip on the two sides, as a low north dip on the upper side and a high north dip in the underfolded strata.

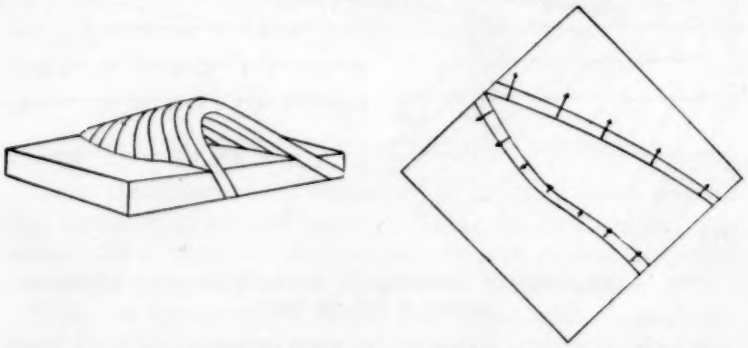
In such a case an overturn is suggested, and if an exposure giving a dip contrary to the general dip can be found, as *c* in C′D′, it has generally been considered as confirming the probable existence of an overturn at that point.

In many cases the only actual evidence obtainable is a single dip or two contrary to the general direction of dip. In such a case,

the suggestion thus given may often be strengthened by the presence of shales, or of the thin bed of novaculite and silicious shale, all of which are believed to be low in the columnar sections and therefore, if exposed at all, would be near the axis. In a few cases the presence of the igneous rock or of parallel outcrops of the thin bedded novaculite and silicious shales was considered as a possible evidence of an anticlinal axis. In only a few cases could the actual continuity of the beds be traced.

When erosion has cut down to the level GH, it is next to impossible to recognize the axis unless a good exposure of rocks low in the series occurs directly in the axis.

When all these fail there has been tried successfully, in cases where the overturn is suspected, the plan of tracing an anticline into the disputed locality. Thus in Fig. 15 a layer of sandstone is



FIGS. 15, 16.—Diagrams illustrating the changes of dip and strike in the development of an overturned anticline.

represented as rising from a low anticline and merging into a high overturn. Were the block planed off, the outcrop would have some such shape as that shown in Fig. 16, on one side the dip remaining constant in direction, and probably not varying much in amount; on the side toward the observer not only is the outcrop curved somewhat, but the low dip at the further side gradually rises, finally becomes perpendicular, and then is reversed by the complete overturn of the fold.

In no case were continuous outcrops of that character found, but the plan used was to select some unusually hard layer or layers involved in the overturn, and to trace them partly by means of outcrops and partly by means of the scattered blocks on the surface,

which resisting decay would indicate the presence of the hard layers beneath. Many of the overturns in the eastern part of the area were worked out in this way.

To resume, overturns may be suggested or located: (1) by the existence of anticlines to the east or west of a given locality; (2) by the prevalence over an unusually broad area of high dips in one direction; (3) by topographic relief; (4) by the exposure in parallel outcrops of deep-seated beds.

VI. Detailed Structure on the Eastern Sheet.

The detailed structure will be described under the artificial divisions made by the two map sheets of the area. The two general divisions of the eastern sheet may be studied under:

1. The Caddo Valley.
2. The area of drift, the Chalybeate mountain being taken as the northern edge of the area of drift.

Eastern Portion of Caddo River Valley.

The Caddo valley may be divided into an east and west portion, the dividing line being in range 22 W.

As will be explained more fully elsewhere, the topography of the portion of the eastern sheet north of the Chalybeate mountain, while broken up by divides and ridges into minor valleys, is a broad valley, differing in many ways from the country south of Chalybeate mountain.

Blakeley Creek Anticline.—The limits of this anticline were not definitely determined, but the ridge produced by it is between 100 and 150 feet high and five miles long, running from 4 S., 18 W., section 27, to 4 S., 19 W., section 26, along the south side of Blakeley creek. The ridge is of novaculite, but the novaculite bed is only poorly exposed. The ridge is serrated (as illustrated under Prairie Bayou anticline, Fig. 16), steep on the north side, the south side forming a water-shed to Prairie Bayou. It is highly probable that this anticline is continued further east, connecting with the one a mile and a half north of Social Hill.

Minor Anticlines.—Two minor anticlines were found in 4 S., 18 W., south half of section 29.

By minor anticlines is meant those in which the evidence of folding is meagre, or which could not be traced or other evidence of

their existence found, or in which the thickness of the beds would indicate a small fold compared with the majority of folds. The evidence in most of these cases is only negative, but many of these so-called minor anticlines may prove to be quite as important as some which better exposures have disclosed more satisfactorily.

The Prairie Bayou Anticline.—Fig. 17 will give an idea of the structure of the Prairie Bayou anticline and of its accompanying topography, which may be taken as a type of the serrated ridges. The topography is a gentle slope draining from the top of the ridge next north leading to a long narrow valley, perfectly flat and covered by a deposit of novaculite gravel. This little valley is bounded on the south by a nearly perpendicular bluff 100 feet high, at whose base flows Prairie Bayou. From the top of the bluff the ground slopes gently south.

The anticline was first observed in the prairie from which Prairie

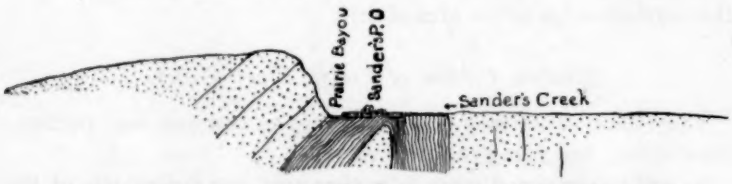


FIG. 17.—Section across Prairie Bayou anticline at Sanders Post-office.

Bayou takes its name in 4 S., 18 W., section 33. At that point it seems to be an overturn of the type C'D', Fig. 14 (preceding chapter). From here it can be traced up the valley of Prairie Bayou, keeping close to the township line between 4 and 5 S., until in 4 S., 19 W., section 31, it becomes a simple anticline. The head of the east and west valley is at this point. It is crossed by the Arkadelphia-Hot Springs road in 4 S., 20 W., section 36, about an eighth of a mile north of the township line. The existence of several good springs on the axis along its western part should be noted. Westward from where it is crossed by the Hot Springs road the country is flat, and no indication of the axis is found until in 4 S., 20 W., section 31, where an anticline brings novaculite to the surface on the Big Hill creek. The ridge is 75 or 100 feet high and half a mile long; it is probably a continuation of the Prairie creek anticline.

Valley Fork Overturn.—In 5 S., 20 W., on the line between sections 3 and 4, De Roche creek cuts through a fifty-foot ridge a

couple of hundred yards north of the crossing of the old Malvern-Murfreesboro road. The upper beds of the novaculite appear at the surface, but in a very small exposure. The structure appears to be an overturn. In 5 S., 20 W., section 6, on Big Hill creek, dips in the shale suggest that this overturn crosses the creek a little north of the half mile line. In 5 S., 21 W., section 4, on the Valley Fork of Point Cedar creek, half a mile north of Valley post-office, a seventy-five foot ridge is cut by the stream, exposing novaculite in thin ledges for a total thickness of 100 feet. The dip is perpendicular, indicating an overturn of the type G'H', Fig. 14. The connection between this and the first exposure is doubtful, but having the same structure, and being in the same strike, it may be assumed that they are the same. West of the exposure on Valley Fork, the overturn can be traced into an anticline which is crossed by a branch of Point Cedar creek in 5 S., 21 W., section 7, northeast quarter. The strike from Valley Fork west is a little south of west. No trace of it was found further west, unless a small anticline on Cox's creek in 5 S., 22 W., section 9, southwest quarter be a continuation of it.

Minor Anticlines.—A small anticline is crossed by the Arkadelphia-Hot Springs road in 5 S., 20 W., in the south half of section 1; and another in 5 S., 20 W., north half of section 9, by De Roche creek.

Bayou Delile Overturn.—The Bayon Delile in its upper course runs east for some distance along the foot of a 75 or 100 foot ridge, finally turns south and cuts through the ridge in 5 S., 18 W., exposing an overturn in the gap with its overthrow to the south. This overturn shows again in perpendicular dips in 5 S., 19 W., section 15. It appears again to the south in 5 S., 20 W., just south of the northeast corner of section 16, on De Roche creek. It has not been found further west.

Minor Anticlines.—In 5 S., 20 W., section 16, close to the southwest corner, on a small branch of De Roche creek, is a small anticline, and again in 5 S., 21 W., section 13, is another or possibly a continuation of the first. In section 26, on the Caddo an anticline with a southwest strike shows very nicely. In 5 S., 22 W., southeast quarter of section 17 and southwest quarter of section 16, near the south section line, anticlines are exposed on Cox's creek. Also in the southeast quarter of section 15 a small anticline is exposed on a tributary of Cox's creek.

Through the centre of 5 S., 21 and 22 W., runs a belt about two and one-half miles broad in which the strata are nearly horizontal, the dip varying from 0° to 25° a little east of south.

De Roche Creek Anticline.—In 5 S., 20 W., the De Roche creek anticline is crossed by the Arkadelphia-Hot Springs road in the centre of the northeast quarter of section 36. Half a mile further west, where the axis is crossed by De Roche creek, Mr. Branner found it well exposed in the bank of the creek. The belt of north dips, a mile broad here, becomes narrow to the west until, as it enters 5 S., 21 W., it is less than a quarter of a mile broad, the axis being crossed by Big Hill creek half a mile from its mouth. It is crossed by the Caddo a mile west, in the northeast quarter of section 35, the strike being deflected a little south of west. It has not been identified further west.

The connection of the axis exposed on De Roche creek with that on Big Hill creek may be strongly questioned, even though the evidence obtained points that way. Theoretically it would be more satisfactory to connect it with the Big Hill creek anticline next described.

Big Hill Creek Anticline.—Just at the mouth of Big Hill creek in 5 S., 21 W., section 36, a ridge (140′) juts boldly out, the rock showing a dip of 88° S. As an anticline crosses the Caddo a mile west of this point in section 35, in the same strike, it is probable that the high ridge is in the axis of an overturn. This ridge is continued west of the mouth of Big Hill creek, forming a narrow divide between the Caddo and Big Hill creek which here runs east and parallel to the Caddo a quarter of a mile before running into it. The south side of this divide is for some distance composed almost entirely of a few bedding surfaces having a dip of 78° S., 2° W. For a mile or two north of where this anticline is crossed by the Caddo the structure is not clear, the dip varying rapidly; evidences of a fault are abundant, but the amount of throw could not be determined.

Caddo River Anticline.—The Caddo river anticline is thought to start in an anticline near the Ouachita river, a little south of the centre of 5 S., 18 W., which is crossed by the military road east of the centre of section 29.

In 5 S., 19 W., an overturn which has been assumed to be on the same anticlinal axis shows nicely on Waterhole branch, a tributary of De Roche creek, in the southern part of section 34. The

overthrow is to the north, of the type G′H′, Fig. 13, and an approximate correlation of strata is possible. In the northern part of township 6 S., ranges 19 to 22 W., is a long shale valley just north of the Chalybeate mountain, occupied to the east by De Roche creek, further west by the Caddo river, and still further west by Brushy creek. In various parts of this valley there is much indirect evidence of an anticline or overturn, but, aside from those mentioned above, at only two places was direct evidence obtained, and that was not very satisfactory. In 6 S., 20 W., section 10, near the northwest corner is a round mound 80–100 feet high giving a dip of 75° N., 7° E. on the north side and 60° S., 2° W., on the south side; and in 6 S., 21 W., northeast quarter of section 12, at the bend in the Caddo there is some appearance of overturning. Scattered perpendicular dips in shales on about the same line would suggest that an anticline or overturn passed through the two points mentioned.

Western Portion of the Caddo River Valley.

In this division the structure is in several cases well displayed by anticlinal ridges which rise sharply from the broad valleys here predominating. The structures in these broad valleys is obscure, as might be expected, and in some portions the shale and interbedded sandstones have been twisted, faulted and jammed together until they defy all attempts to work out the original structure.

In 5 S., 22 W., Dr. J. P. Smith reports[1] four anticlines north of the Caddo river, the most southern of which is probably the same as the overturn giving the novaculite ridge north of Rock creek. It is probably this anticline which appears at the bend of the Caddo in 5 S., 23 W., section 17.

Sugar Loaf Creek Anticline.—In 5 S., 23 W., in section 1 or 2, near the section line, on Sugar Loaf creek is one of the few examples of an anticline where the axis is exposed, showing the beds closely bent on themselves. This exposure occurs at a road crossing where the creek makes a sharp turn to the east. It may be a continuation of one of the anticlines found by Dr. Smith.

Caney Fork Anticline.—In 5 S., 23 W., at the bend of the Caddo in section 11 is another case of an overturn showing well in the

[1] *Geol. Surv. of Ark.*, Rep. for 1890, Vol. iii, Mount Ida sheet.

axis.[1] The axis is crossed by the Caddo again in section 16 near the mouth of Caney Fork. It forms a fifty-foot ridge running along the south side of the Caddo. In section 16 it is crossed by the river again just south of where it turns east, and again a quarter of a mile further west in section 17. In 5 S., 24 W., there is an overturn in the northern part of section 24 showing poorly on and near the Amity-Rock creek road. This may be a continuation of the preceding, and if it is, it is probable that this anticline may be considered as running up the Rock creek valley near the middle east and west section line of the township. It is the determining factor in the structure of the northern part of Pine mountain.

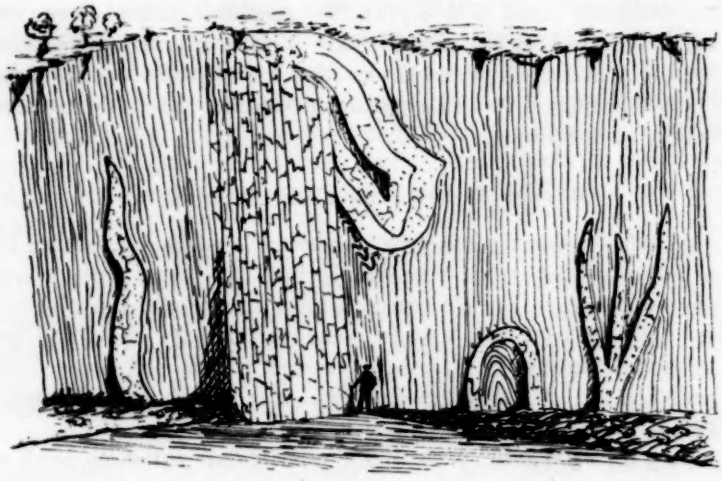


FIG. 18.—Contorted sandstone, shale, and novaculite exposed on the Caddo; 100 feet wide by 50 feet high.

In 5 S., 23 W., the northwest corner of section 21, on the Caddo, is one of the best exposures of the thin bedded novaculite and silicious shales and in the shales, on either side are good examples of contorted strata. Fig. 18 shows the wrinkling of these beds. There is also here a small but good example of a reversed fault having a throw of two and one-half feet.

Sugar Loaf Mountain Anticline.—In 5 S., 23 W., the northeast

[1] Photographs were obtained of many of the more interesting structural features of the region, but through an accident nearly three dozen of the best negatives were destroyed when it was too late to replace them.

quarter of section 14 is a sugar-loaf-shaped knob of novaculite about 200 feet high making a conspicuous landmark, as the country for a few miles in every direction is comparatively level. This may be a continuation of the Haw Knob anticline, the evidence being insufficient to decide the question.

The Haw Knob Anticline.—The Haw Knob anticline is first met with in a small ravine in 5 S., 23 W., about the centre of section 22. Half a mile southwest it is crossed by the Amity-Caddo Gap road, novaculite being exposed on either side of the road. Running southwest the novaculite produces a ridge which, though broken at two places, rises until at the western end, in the northeast quarter of section 29, where it is nearly three hundred feet high, it forks and ends abruptly. Farther west it appears to be continuous with an anticline on a branch of Antoine creek in section 30 northwest quarter and another anticline a mile further west in 5 S., 24 W., section 25, quarter of a mile north of the centre. The inter-

FIG. 19.—Section across a stream following an anticline.

mediate structure, however, is too broken to allow of direct connection being traced.

This structure seems to show that Pine mountain, running east and west through the centre of 5 S., 24 W., is synclinal in its structure.

Minor Anticlines.—Between the Haw Knob and Amity anticlines the structure seems to be a syncline with the layers near the surface crumpled into a number of small folds. Along the Amity-Caddo Gap road in 5 S., 23 W., section 27 and 22, several anticlines are exposed. On the Caddo, in 5 S., 23 W., section 13, two overturns are exposed, one on the east bank close to where the Caddo crosses the south section line of section 13, and the other on the western side at the mouth of a small drain a little below where the Caddo crosses the west section line of section 13. The latter fold is a gaping anticline along which the stream flows. Fig. 19 shows a section

across the fold. Exposures of igneous rocks are common in the region of these small anticlines.

Amity Anticline.—The Amity anticline is first noticed as a nose on the Caddo in 5 S., 23 W., near the centre of section 24. By means of a quartzite layer it was traced southwest into the novaculite ridge just north of Amity. It makes a low rise, exposing novaculite just east of the Amity-Hot Springs road in the southeast quarter of section 27; it forms the low ridge, seven hundred yards long, just north of Amity. This anticline can be traced by means of the large novaculite blocks strewn on the ground for a quarter

FIG. 20.—Faulted sandstones near Amity, Clark county (5 S., 23 W., section 30, S. E. quarter).

of a mile west of the end of the ridge along the direction of the strike. Where it crosses a small drain in section 33 the horizontal outcrops of the rocks are sharply bent, without fracturing, through an arc of 110°. In the northeast quarter of section 31, an anticline in the same strike crosses a tributary of the north fork of Antoine creek. It has not been distinguished further west. Near the last mentioned exposure is a curious example of faulting of the rocks; it is illustrated in Fig. 20. This fold is of interest as being the most southern anticline to bring thick bedded novaculite to the surface. The structure is overturned where the novaculite is exposed.

Minor Anticline.—In 5 S., 23 W., section 31, the southeast quarter, the dips indicate the existence of an anticline which is seen

again in the same strike in 6 S., 24 W., section 2, where a small drain crosses the township line, near the north and south half-mile line of the section. This region between the Amity and Big Bear anticlines has been very badly crushed in 5 S., 23 W., sections 31 to 33. Fig. 21 is an example of crushing in shale exposed in a

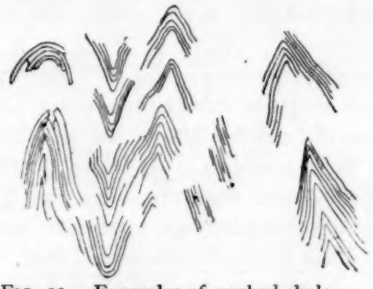


FIG. 21.—Examples of crushed shale in 5 S., 23 W., section 33.

creek bottom in section 33, northwest quarter. In the southwest quarter of section 33, at the junction of two small creeks, is a fault with an offset in the outcrop of several yards, the sandstone layers being sharply jammed together and the shales tightly squeezed. Fifty yards from this point up the stream that enters from the west, the way the shales are crowded upon the end of a hard layer of

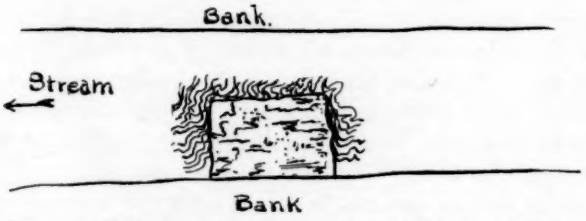


FIG. 22.—Shale in the bed of a stream showing secondary movement.

sandstone suggests that the movement may have taken place since the stream eroded away the part of the hard layer which is gone (see Fig. 22).

An Overturn.—In 5 S., 22 W., section 32, near the northwest corner are evidences (stronger in section 31, north of centre of section) of an overturn. The overturn follows up a little creek,

the thin bed of novaculite and siliceous shale being exposed along the axis. In 5 S., 23 W., the axis strikes S., 20° W., across section 33 to 36, being readily traced by the fragments of novaculite over the surface. Passing into 6 S., 23 W., it follows the same course, the novaculite being exposed on both sides of the axis. In 6 S., 24 W., it crosses the north fork of Antoine creek just north of the crossing of the Alpine-Kirby road, where the anticline is no longer overturned.

Big Bear Mountain Overturn.—The Big Bear mountain overturn is almost in the strike of the last-mentioned one, but at the eastern end it seems to be deflected to the south. This anticline starts in 6 S., 24 W., section 11, southeast quarter, runs a little north of west for half a mile, then turns and runs S., 70° W., into 6 S., 25 W., on the western sheet, the southeast quarter of section 14 at the crossing of the Kirby-Murfreesboro road.

The Little Bear mountain, to be described later, is in this same strike, but its eastern end is deflected south, much as the eastern end of the Big Bear mountain is; otherwise the Bear mountains and the preceding anticline might be considered as a single anticline from the Caddo to the Little Missouri.

The Big Bear mountain anticline produces a high, sharp, irregular ridge. This ridge, which is about three hundred feet high, rises from a low, flat country and so makes a conspicuous landmark. It is the best example of an overturned anticlinal ridge in the region. The crest is sometimes as sharp as the roof of a house, the hard layer which makes this crest in many places forming the south flank of the mountain for a score or two of feet from the top with a dip of 67°. In several places where there is an exposed dip on the crest of ten or fifteen feet in length, springs start out from the very top of the ridge. In 6 S., 24 W., between sections 16 and 17, it is cut square in two by Gap creek.

While this may be due to the same causes that have allowed the main streams to run south across the strike of the beds, in this case the explanation seems to be that it is due to a backward cutting stream, an excellent example of which is a small stream on top of the ridge farther east. One of the little channels starting from a depression in the crest, as shown in Figs. 23 and 24, has cut its way along the top but on the side of the crest opposite to that down which it flows. This has continued until the channel extends for some distance along the top and has made a deep gap of the

original depression from which it flowed. Given time enough, there will be formed at that point a gap cut clear to the bottom. The

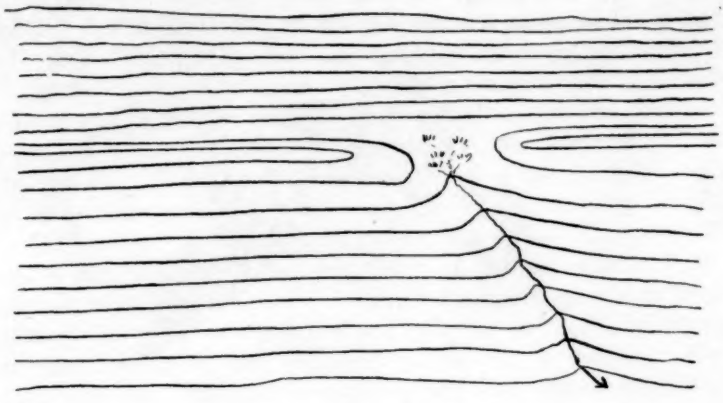


Fig 23 Early stage

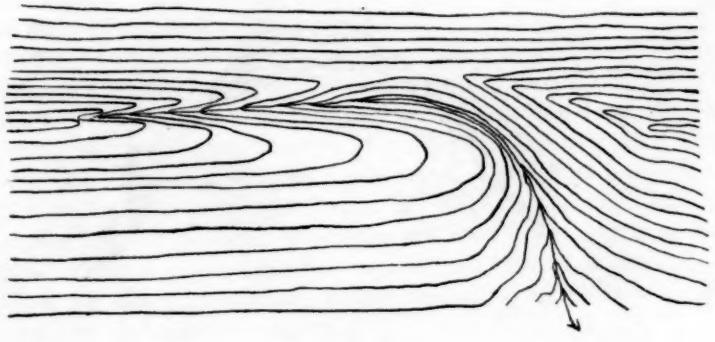


Fig 24 Later stage

FIGS. 22, 24.—Top of Bear Mountain, showing the development of a gap.

structure of this ridge can be seen at the gap, and at a few places along the top.

Alpine Anticline.—The Alpine anticline was first noted in 6 S., 22 W., Sec. 9, northeast quarter, in parallel outcrops of thin bedded novaculite and siliceous shale. It is crossed by the Alpine-Amity road half a mile northwest of Alpine. In 6 S., 23 W., it can be traced across sections 13, 14, 15 and 16, having a strike a

Fig. 25

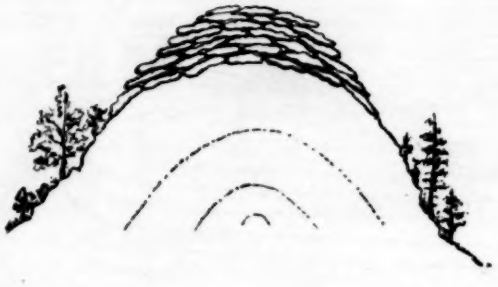


Fig. 26

FIGS. 25, 26.—Profiles of Antoine mountain, Pike county, Arkansas.

little south of west. It appears to be crossed by the Amity-Murfreesboro road in section 19, southwest quarter. It has not been found to the west.

Minor anticlines occur in the same township southeast quarter of section 8 and north half of section 17. Their extent is unknown.

Antoine Mountain Anticline.—Questionable traces of the Antoine mountain anticline appear in 6 S., 23 W., near the centre of section 22. In section 19, it forms a ridge extending westward into 6 S., 24 W., through the south half of sections 23 and 24, and probably forms the ridge across the township along the south side of Woodall's creek. The main ridge is two hundred to three hundred feet high, and is chiefly interesting on account of the anticlinal wall on its summit. This (see Figs. 25 and 26) is a low irregular wall about a quarter of a mile long, from the side resembling an old, ruined fortress. It varies in height and thickness. On the north side it is in places 15 to 20 feet high; on the south side it is frequently 40 feet high, and in thickness it varies from a wall from 3 to 6 feet thick to a mound-shaped pile of stones. The layers are not continuous, but the break is not due to faulting. The wall is composed of a pile of lenticular rock masses suggesting that while being bent the layers give way in small blocks, and these, under great pressure or tension, have elongated and assumed the shape and position as shown, and have been left behind by erosion. The theoretical consideration of this is taken up in VIII. The rock at this point is a firm white standstone showing little or no signs of metamorphism.

Minor anticlines.—There are two anticlines in 6 S., 24 W. One first noted in section 24, southwest quarter, was traced a little south of west to the centre of section 27. It makes a one hundred foot ridge and probably continues in the same course westward. The other one forms the low ridge just north of Caney Fork post-office, running from the centre of section 26 through the south half of section 27, and probably continues westward. Judging from the fact that traces of manganese show at the top of the last-mentioned ridge, the heavy novaculites, or the horizon at which they occur, cannot be far below the surface.

The Region of the Overwash.

As only four of the anticlines in the region of the overwash were definitely found at more than one locality, those four will be spoken of first.

The Mill Creek Anticline.—In 7 S., 21 W., northwest quarter of section 24, on Mill creek, an anticline is reported by Dr. O. P.

Hay[1] having a strike about 20° north of west. In this same strike Prof. T. C. Hopkins of this survey found an anticline on Bell's creek in 7 S., 21 W., section 18, northwest quarter, and also in 7 S., 22 W., section 11, southwest quarter, on Terre Noir creek, This anticline having a strike of N., 7° W., runs at a high angle to the general trend of the structure of this region.

Straight Mountain Anticline.—The relation of the Straight mountain anticline to the structure of the Chalybeate mountain to the east is not known; it is assumed as starting at Antoine creek in 6 S., 23 W., section 33, southeast quarter. It produces an anticlinal ridge, known as the Straight mountain, from two hundred to three hundred feet high, running a little south of west into 6 S., 24 W., section 36, and from this point is continued as the Wall mountain. It is broken at one point by Kirkland creek, which makes a gap in it.

Wall Mountain Anticline.—Wall mountain anticline is a continuation of the Straight mountain fold, and runs south of west to the Little Missouri river, which it reaches in 7 S., 25 W., southwest quarter of section 7. Starting from the Hot Springs road in 6 S., 24 W., section 36, for about a mile it forms an anticlinal ridge three hundred feet high; beyond this a little stream has cut its way into the anticline, and lowered it somewhat. This gives an excellent example of a breached anticline (Figs. 27 and 28).

In the sections given in Fig. 27, I shows the profile of the high unbroken ridge in the background toward the east; II, III and IV are successive profiles coming toward the foreground (westward), showing the cutting down of the centre of the ridge by the stream which originally cut in, and now drains by way of the gap shown in section IV; the full line gives a section on the west side of the gap. One of the interesting features of this ridge is shown in the illustration. This is a great wall, at one place about sixty feet high, crowning the summit of the north arm of the ridge for more than half a mile. It is composed of a layer of hard sandstone eight feet thick, rising perpendicularly. The manner in which it has withstood erosion is due partly to its hardiness and partly to its being so exactly vertical that detached masses simply rest in their places. The outcrop of the same layer of rock shows along the summit of the southern arm.

This weathering of the rocks in vertical walls is not uncommon

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, p. 271.

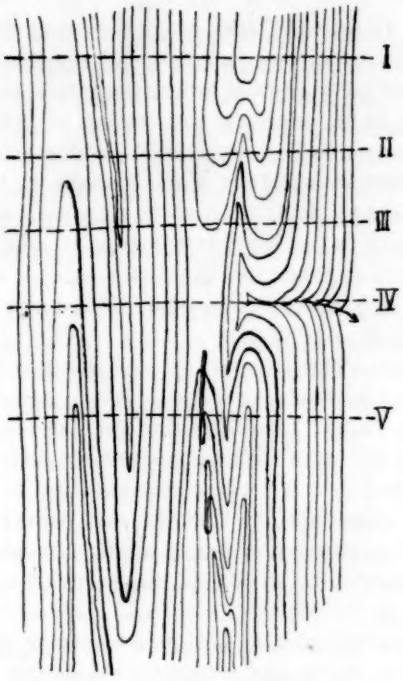


Fig. 27

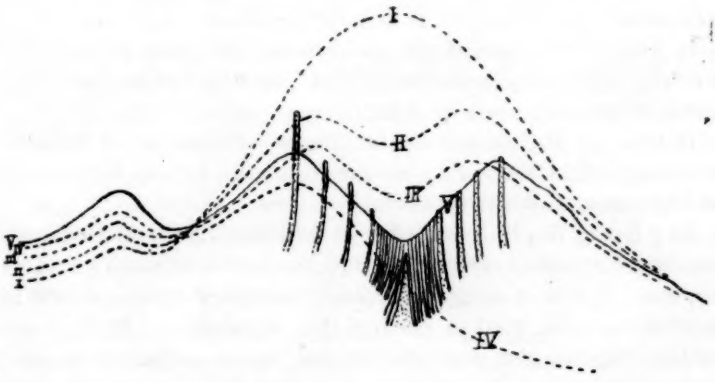


Fig. 28

FIGS. 27, 28.—Map and sections of Wall mountain.

on a small scale. In several places, where the heavy layers of sandstone are perpendicular at their outcrops, the topography is characterized by these irregular parallel walls, from two or three to ten feet high, running as far as the eye can reach.

Suck Creek Overturn.—The Suck creek overturn was only seen in 8 S., 23 W., first showing on a small creek in the southeast quarter of section 13. It is crossed by Antoine creek near the mouth of Suck creek in the southwest quarter of section 11, showing nicely in a small exposure on the east bank. It was traced up Suck creek about two miles; it appears to be an overturn all the way. Its strike is N., 65° W.

Other Anticlines.—The structure of the Chalybeate mountain was not solved, but the evidence suggests that it is an underthrown syncline, with the Caddo river anticline on one side, and on the south side an anticline of which no trace was found, unless there could be considered as such, perpendicular dips in 6 S., 22 W., section 13, near where the old Camden road leaves the Arkadelphia-Mount Ida road, or an exposure of shales apparently in the axis of an overturn in 6 S., 20 W., northern part of section 26, on the Caddo.

In 7 S., 21 W., section 10, an anticline is crossed by a tributary of Winfred creek in the northern part of the section, and another is crossed by Winfred creek in the southwest quarter. These have a strike of S., 65° W. In section 6 an anticline is crossed by Bell's creek in the southwest corner of the section with an east and west strike.

In 6 S., 22 W., section 36, an anticline was found at the end of a ridge; it probably continues to the Terre Noir, forming a ridge which runs a little south of west.

In 6 S., 23 W., there is an anticline or overturn just at the south township line in section 34 on the Antoine. It may be the cause of the valley of White Oak creek.

In 7 S., 23 W., it is probable that there is an anticline in the east and west valley running through the centre of sections 12, 11, 10, etc. Traces of manganese found near Story's store, section 10, southeast quarter, tend to confirm this supposition. In the centre of the township the strata for several square miles are so nearly perpendicular that a variation of a very few degrees gives the appearance of an anticline, so that it is impossible to tell which are anticlines and which are not. In section 22 is a large, flat area,

and the evidence of an overturn here are somewhat stronger, chiefly the presence of shales with north and south dips. In the southern part of section 27, on the west bank of Antoine creek, a long bluff, seventy-five feet high, gives an excellent exposure of rock, and on either side of one point the layers bend toward each other in such a way as to suggest the axis of an overturn. Bluff mountain, a quarter of a mile farther south, also gives a fine exposure. An anticline probably crosses the big river-bottom in section 34, 7 S., 23 W.

In 7 S., 24 W., high dips and a ridge one hundred feet high, crossing Wolf creek near the centre of section 21, suggest the probability of an overturn with a strike S., 70° W. This is in the strike of an overturn on Prairie creek, to be described later.

VII. Detailed Structure on the Western Sheet.

Township 4 South.

Rachel Mountain Axis.—Rachel mountain is a novaculite ridge in the northern part of 4 S., 30 W., and has been described in the report on novaculite.[1] Its axis crosses the Brushy Fork of the Cossatot in 4 S., 30 W., section 5, southwest quarter. It ceases to be a novaculite ridge before reaching the Brushy Fork. In the same strike in 4 S., 32 W., section 1, half a mile south of Cove, an anticline is crossed by the line road, and traces of it are found in 4 S., 31 W.

Buffalo Creek Anticlinal Axis.—This axis is reported by Mr. Means[2] as crossing the Brushy Fork in 4 S., 30 W., section 7, the southwest quarter, near the mouth of Horn creek.

In 4 S., 31 W., it was noted again in section 12 and in section 10; the presence of igneous rock and the topography across that row of sections suggest its continuity in a due west direction.

In 4 S., 32 W., Mr. Means found the axis crossing the Old Line road near the middle of the section line between 11 and 12. A few uncertain dips indicate that it continues westward, and that it determines the Buffalo creek valley.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 262.

[2] Mr. J. H. Means, assistant geologist of this survey, worked up considerable of the area included in 4 and 5 S., 30 and 32 W. Most of the structure in 30 W. was gone over to get its connection and relation to the structure further east. That in 4 and 5 S., 31 and 32 W., is largely taken directly from Mr. Means' notes.

Mr. Means also reports an anticline or overturn on Brushy Fork in 4 S., 30 W., section 17, northwest quarter.

Barn Creek Anticline.—Raspberry mountain is a novaculite ridge crossing 4 S., 29 W., near the centre, and reaching the Cossatot in 4 S., 30 W., section 14, southeast quarter. Following this strike there is an anticline in sections 17 and 18, south part, which Brushy Fork crosses three times with an S-shaped curve, and in the southwest quarter of section 18 it is crossed by Rock creek.

Further west it is followed by Barn creek, and shows as an anticline near where the Old Line road crosses Barn creek in 4 S., 32 W., section 13.

To the west Mr. Means found this axis to be replaced by one a quarter of a mile further south. Barn creek swings south and follows the last axis quite closely across 4 S., 32 W.

Pontiac Anticline.—The end of a long novaculite ridge crosses the Cossatot in 4 S., 30 W., northwest quarter of section 22, just north of Pontiac post-office. It runs out as a ridge a mile to the west where it has a strike a little south of west. In this strike, in section 20, the northwest quarter, an anticline is crossed by Brushy Fork.

West of this point no anticline was found until 4 S., 32 W., section 19, where Mr. Means reports an anticline crossing Hickory creek near its junction with Buffalo creek.

Anticlines on the Cossatot.—In 4 S., 30 W., two small anticlines are crossed by the Brushy Fork in section 20, one near the north section line and the other a little more than a quarter of a mile further south.

About a quarter of a mile from the south side of section 20 (4 S., 30 W.), Brushy Fork and the Cossatot are separated by a high but narrow neck of land, ten to twenty yards wide. They diverge, however, and flow together a mile further down. On the Cossatot side of this neck is exposed the fault shown in Pl. VIII.

This same fault shows again in section 21 at the first bend in the Cossatot south of Pontiac post-office. It is really a double fault, as shown in the Cossatot section on Pl. I.

In the same township, section 30, near the half-mile line, the Cossatot crosses an overturned anticline. A quarter of a mile below, in the southwest quarter of section 29, the Cossatot crosses another anticline, and near the south section line of section 29, it

crosses still another. This last anticline is in the same strike as one crossed by Baker creek near the south section line of section 25 of the same township. In section 31, southeast quarter, the Cossatot crosses an overturned anticline, as shown in Pl. II.

Hickory Creek Anticline.—In 4 S., 31 W., section 26, southeast quarter, an anticline is crossed by Flat creek. In this same strike Mr. Means reports an anticline crossed by the Old Line road in 4 S., 32 W., section 25, southwest quarter. Going westward it forms a low ridge which separates the two branches of Hickory creek. This fold was not seen west of sections 28 and 33. An anticline was found by Mr. Purdue in 4 S., 29 W., section 35.

A few other minor folds were noted.

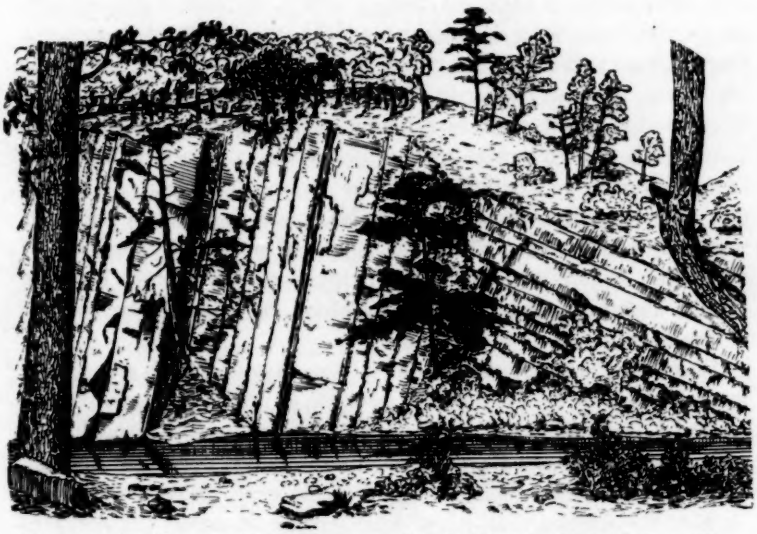


FIG. 29.—Fault on the Cossatot near the Mouth of Brushy Fork (4 S. 30 W., Sec. 20).

Structure in Township 5 South.

Novaculite Ridges.—As the novaculite ridges have been described in detail in the report on novaculite[1] they will only be mentioned here. In 5 S., 25 and 26 W., the northern two tiers of sections are occupied by novaculite ridges; Brook's mountain, North mountain, Warm Spring mountain, Line mountain, and others. In 5 S.,

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Chap. xiii.

27 W., the end of Line Mountain crosses sections 1 and 2, and Raven mountain, with a south of west strike, enters sections 4 and 5. Between sections 5 and 6 it is cut by the Little Missouri river, the anticlinal structure showing distinctly. West of the Little Missouri it strikes a little north of west, and under the name of Prairie mountain crosses the northeastern section of 5 S., 28 W., gradually entering 4 S., 28 W. It is crossed by the Saline at Moore's mill, in section 31, and it comes to an end a mile or two further west.

In 5 S., 31 W., a novaculite ridge, called the Cross mountain, rises in section 2 and runs out at the Line road in 5 S., 32 W., in the northern part of section 1.

In 5 S., 32 W., the southern part of section 1, are two short novaculite ridges in the same strike. The Line road passes between the two through what is known as "the gap." In the southeast corner of section 2 another ridge rises and runs west to the gap at the head of West creek, in the southwest quarter of section 3. West of this gap it rises to a height of 450 feet, and is known as Potato hill, then it runs a little south of west and passes out of the State at section 7. Between sections 11 and 14 the South mountain begins, strikes west for two miles, where it is cut by the head waters of Cross creek, then runs south of west and passes out of the State in section 18. These ridges continue west into the Indian Territory, but how far and how important they become is not known.

Ball's Branch Anticline.—Ball's Branch anticline is crossed by the Saline river in 5 S., 28 W., section 6, near the centre of the section.[1] In 5 S., 29 W., this same anticline passes through sections 1 and 2, crosses Harris Fork in section 2, northwest quarter. Though the anticline was not found to the west, ridges which occur in its strike suggest that it, at least, continues across the northern edge of 5 S., 29 W.

In 5 S., 30 W., the Cossatot crosses an overturn near the north section line of section 6.

The Watkins' Mill Overturned Anticline.—The Watkins' mill fold is a simple anticline where crossed by the Saline in 5 S., 28 W., section 5, on the south section line.

Where it is crossed by Harris Fork at Watkins' mill, in 5 S.,

[1] Practically all the structure of ranges 28 and 29 W. was worked out by Prof. A. H. Purdue, Professor of Geology at the Arkansas Industrial University, formerly assistant on the Geological Survey.

29 W., in the southeast corner of section 3, a recent exposure made in the bank shows the strata making a complete overturn. Prof. Purdue reports this to be an unusually fine illustration of an overturn. The overthrow is to the south. Though this fold was not found further west, the monoclinal ridge just north of it was traced across the township, indicating that the anticline continues across the township with a strike a little north of west.

In 5 S., 30 W., there is probably an overturn in sections 6 or 7 —an eastward continuation of the Cross mountain. Only north dips were found, however.

Minor Anticlines.—In 5 S., 28 W., section 8, northeast quarter, the West Saline crosses an anticline a little below Lance's mill, and in the centre of the southeast quarter of the same section there is another one. In 5 S., 29 W., there were found, corresponding to these two anticlines, two doubtful anticlines on Harris Fork; one a quarter of a mile south of Watkins' mill in section 10, and the other a quarter of a mile north of the southwest corner of section 11.

Prior Ridge Anticline.—In 5 S., 27 W., the structure and topography suggest an overturned anticline in the northwest corner of section 17. It is overthrown to the north. At the Little Missouri it is hidden in bottom land, but a short distance west of that stream it makes a ridge between White Oak creek and Clover creek, which gives evidence of anticlinal structure. This ridge was traced a little south of west to the Saline, where the structure is anticlinal. From the Saline to Harris Fork it could not be traced, but an anticline crossed by Harris Fork in 5 S., 29 W., northeast quarter of section 15, is in the same strike and may be the same axis. This last anticline may also be on the same axis as an anticline on Moore's creek, section 16, northwest quarter; the intermediate topography exhibits no clear structural relations.

An anticlinal ridge extends from Moore's creek to the Cossatot; the anticlinal structure is shown where it is cut by Moore's creek in 5 S., 29 W., northwest quarter of section 16. The ridge then runs a little north of west to 5 S., 30 W., southwest corner of section 12, showing the anticlinal structure north of Eldridge post-office in 5 S., 29 W., section 18, northern part.

In 5 S., 30 W., it is known as Prior's ridge, and it runs due west from section 12, the anticline showing where cut by Baker creek in the southwest corner of section 11, and as an overturn where cut by the Cossatot in section 7, southeast corner. From

the Cossatot westward the shales which are exposed on the Cossatot have been eroded, producing in 5 S., 31 W., the Prior creek valley. This anticline, if produced into 5 S., 32 W., will join with the South mountain anticline.

Minor Anticlines.—In 5 S., 29 W., a small anticline is crossed by Harris Fork in section 15, the southeast quarter. In 5 S., 30 W., parallel outcrops of the thin novaculite seem to indicate an anticline or overturn in section 17, northeast quarter. In 5 S., 32 W., section 16, northwest quarter, two small anticlines are cut by Cross creek.[1]

Baker Spring Ridge Anticline.—In 5 S., 27 W., the Little Missouri river crosses an anticline in the northwest quarter of section 16. This anticline runs a little south of west, forming a two hundred foot ridge between Clover creek and James creek. In 5 S., 28 W., it is crossed by the Saline in the southeast corner of section 16; from this point it runs due west, being crossed by Harris Fork in 5 S., 29 W., section 15, in the southeast corner. On the south side of the anticline, between Harris Fork and Moore's creek, is a two hundred to two hundred and fifty foot ridge, highest at the Harris Fork end. It passes south of Baker Spring in 5 S., 20 W., section 14, southeast corner, and where cut by Baker creek, in section 15, southeast corner, there is one of the best exposures of an anticline in the whole area.

Going west the ridge made by this fold rises to a height of two hundred to two hundred and fifty feet. It is crossed by the Cossatot in the southeast quarter of section 17. In the centre of section 17 is the fine exposure known as the Falls of the Cossatot. The topographic effect of these heavy ledges is seen in the long high ridge between Prior creek and Cow creek, which runs across 5 S., 31 W. In the southeast quarter of section 14 and in the same strike to the east, shales are exposed structurally identical with the shales just under the heavy novaculite exposed in the Prairie mountain anticline on the Little Missouri river. Baker Sulphur Springs issue from this shale.

West of the Cossatot Mr. Means found this anticlinal axis in 5 S., 32 W., section 13, southeast quarter.

Mill-site Branch Anticline.—In 5 S., 27 and 28 W., the Mill-site branch anticline was not surely found, but the presence of thin-bedded novaculite shales, horizontal dips and the topography sug-

[1] All structures on Cross creek were worked out by Prof. A. H. Purdue.

gest its existence parallel to, and a little over a quarter of a mile south of, the last-described axis. In 5 S., 29 W., it forms the valley of Mill-site branch through sections 23 and 22. At the mouth of the creek a small fall in Harris creek offers some water power. North and south of the Mill-site branch valley are high ridges, the southernmost one being synclinal in structure. From Harris Fork to the Cossatot in 5 S., 30 W., section 21, northwest quarter, the continuity of the structure is clearly defined by the long ridge north of the Harris Fork valley and ridges between Baker creek and the Cossatot in 5 S., 30 W. Mr. Means crossed the anticline in the northwest quarter of section 20, but it was not found further west in 5 S., 31 and 32 W. To the east of the Little Missouri no anticlines were found in this strike, but the topography of the Pine mountain in 5 S., 26 W., in section 15, south of Lodi post-office, gives every evidence of being an anticline, probably an overturn.

The ridge, which, for the most of its length, is not conspicuous, here becomes one hundred and fifty feet high, and this anticline again may be in the same axis as the overturn south of Rock creek post-office.

Blocker Branch Anticline.—Corresponding in strike with the overturn in the south part of Pine mountain in 5 S., 24 W., as carried out by the topography, is an overturn on the Little Missouri river in 5 S., 27 W., sections 21–23. This overturn is visible at a number of places along the river, the bending showing nicely at the foot of the road just north of Mr. Logan's, north of the centre of section 22. This fold is remarkable for the low dip on the south side.

FIG. 30.—North-south section along the Little Missouri river.

The exposure as given in Fig. 30 is two miles long. Pine mountain, shown in this section, is an abrupt ridge on the northern edge of sections 26 and 27 over two hundred feet high, though it maintains this height for only a mile or two to the west. There is probably a fault just north of this ridge, as seen in the section in Fig. 30.

West of the Little Missouri the course of the anticline is shown by the low ridge north of Blocker branch. But it could not be

traced to the Saline river, and, as the structure there is quite different, it will be considered as confined to 5 S., 27 W. Attention is called to the northeast direction of the streams in sections 28–30.

Sulphur Spring Branch Anticline.—The structure in 5 S., 29 W., is not clear, but the topography and the shales go to show that the Blocker branch axis is followed by the Sulphur Spring branch anticline in sections 22–24, and from Harris fork to Baker creek the shale it exposes is a factor in the breadth of the valley of Harris creek.

In 5 S., 30 W., from Baker creek west, this fold forms a two hundred and fifty foot ridge, the structure showing at several places where cut by ravines. In this ridge the shales appear well up in the ridge, while blocks of novaculite lying on the highest point of the ridge indicate the presence of the layer of thin novaculite.

Reverting to the question of the age of this thin bed of novaculite, and referring to section 2, Pl. ii, it is readily seen that if the novaculite occurring thus on top of this ridge be Lower Silurian, as the main body of novaculite is supposed to be, we should have at this point a belt from one to two miles broad in which almost nothing but Silurian rocks are exposed.

To the west of the Cossatot no anticline was noted in this strike, but it is probable that it influences the topography of Cow creek valley in 5 S., 31 W.

Harris Creek Anticline.—The Harris creek anticline is crossed by the Saline in 5 S., 28 W., at the north section line of section 28. Thence it passes nearly due west, helping to form the high ridge south of Sulphur spring branch, in 5 S., 29 W. It then becomes part of the Harris creek valley, and is followed by that creek most of the distance. It is crossed by the Cossatot in 5 S., 30 W., at the north section line of section 26. The structure of the fold is well shown where cut by the Cossatot. From this point it trends due west, forming a high ridge for over two miles on the south side of the Cossatot, which, for that distance, flows through a deep narrow gorge between this ridge and one just north of it made by the Sulphur spring branch anticline. The river flows in the trough of the syncline between these two anticlines, in places being walled in by parallel, almost perpendicular layers of sandstone, which give it the appearance of a canal. There is an anticline on this same axis in 5 S., 31 W., section 26, northern part.

Minor Anticlines.—In 5 S., 28 W., an anticline is crossed by the

Saline river in section 28, northwest quarter, a quarter of a mile south of the Harris Fork axis. At the same distance south of the Harris Fork axis, where it is crossed by the Cossatot in 5 S., 30 W., is an anticline corresponding to the one exposed on the Saline.

In 5 S., 32 W., a small anticline is exposed on the Rolling fork in section 25, a little south of the centre of the section, and a quarter of a mile further south another one is crossed by the same stream. In the strike of these two anticlines, two anticlines are crossed by Cross creek in section 29, southwest quarter. They may therefore be considered as on the same axis.

Umpire Anticlinal Axis.—In 5 S., 28 W., the Umpire anticline forms a ridge in the northern part of sections 34 and 33, and is crossed by the Saline in the northwest of the northwest of section 33. Further west in section 31 it is crossed by a small stream in the southwest of the northeast, near an old mill. In 5 S., 29 W., it is indicated by the dip in section 35.

In 5 S., 30 W., it is crossed by the Cossatot in the centre of the northwest quarter of section 36. In 5 S., 32 W., section 32, southwest of northwest, an anticline is crossed by Cross creek. Though in the same strike this can hardly be assumed to be a continuation of the anticline further east.

Possum Creek Anticline.—In 5 S., 29 W., an anticline runs close to the south township line. In 5 S., 30 W., sections 35 and 36, the Cossatot crosses the same anticline near the south township line. The topography, which east of the Cossatot is a valley, to the west becomes a prominent ridge. It runs west along the township line south of Possum creek and is found to be an anticline where crossed by the Rolling Fork just south of the township line, in 6 S., 32 W., section 2, at the ford of the Eagletown road. Igneous rock is exposed in the axis at the last named place. There is an anticline crossed by Possum creek in 5 S., 31 W., section 35, northwest of southeast, but the topography shows that it cannot be on this axis.

Other Anticlines.—In the Carboniferous portion of 5 S., 25 and 26 W., the structure is but little exposed. The streams seldom have deep channels and the dips found are universally south, except for a quarter of a mile along Bear creek in 5 S., 25 W., section 34, northwest of northwest. This last mentioned dip discloses the only anticline definitely known in the township, though in some places the bending of the rock suggests overturns. Slickensides abound

all over the region, but there is an unusually fine example of them in 5 S., 26 W., section 24, southeast quarter, where the edges of the heavy layers having a dip of 25° are polished horizontally. Such cases are common and are evidence of faulting, even though no other testimony be obtained. In this case Self creek has followed the fault and has been carried three-quarters of a mile eastward.

In the same section, a little south of the centre, the rocks and topography suggest an overturn with a strike of about S., 73° W. In 5 S., 26 W., section 28, southwest quarter, on Rock creek in the same strike, the rocks are sharply curved, and further west in section 31, southwest of northwest, an anticlinal axis shows well on the east branch of the Little Missouri. The structure at this last exposure is shown on the left of Fig. 30, the fault being introduced to account for the sudden change of dip.

In 5 S., 27 W., section 25, southwest of southeast, on the Little Missouri river, a heavy mass of sandstone, showing no bedding and of unknown extent, appears to have been forced up or down through a thick exposure of thin-bedded shaly sandstone. The great quantity of slickensides in every direction in it seems to preclude the idea of its being an unconformity.

The Structure in Township 6 South.

Little Possum Creek Anticline.—In 6 S., 28 W., the Little Possum creek axis is crossed by the Saline river in section 8, northwest of the northwest. It is exposed next in 6 S., 30 W., forming a ridge south of White Oak creek and showing well its structure at the end of the ridge in the northwest of the northwest of section 10, and also in section 9, northwest quarter. In 6 S., 31 W., this axis is followed by Little Possum creek. In 6 S., 32 W., it is crossed by the Rolling Fork in section 12, northwest quarter.

Galena Synclinal Axis.—Just south of the last described anticlinal axis and parallel to it are two other anticlines. The northern one is crossed by the Saline river in 6 S., 28 W., section 8, southwest of northwest, the other one is crossed by the same stream half a mile further south. In 6 S., 29 W., only the southern one was found, following the south section line of sections 10, 11 and 12. Galena post-office is on the syncline between these two anticlines. The two folds form a single flat-topped ridge which slopes off to

the south very gradually. In 6 S., 30 W., the northern one is crossed by the Cossatot in section 9, southwest quarter, and the southern anticline in section 17, northwest quarter. Further west their presence is indicated only by finding outcroppings of igneous rock in 6 S., 32 W., section 9, southeast of southeast, in the strike of the northern anticline and in the strike of the southern one in section 14, northwest quarter, on Rolling Fork and on the bluffs above.

Brushy Branch Anticline—The Brushy branch anticline is the northernmost of the three anticlines that are crossed by the Little Missouri river in 6 S., 27 W., section 12. It is in the northeast of the northwest quarter, nicely exposed in shales, and is overthrown to the north. Just north of it in section 1, where the river runs southwest, a syncline shows on the east bank. It was noted in section 9, northeast of southeast, south of Brushy branch, with a strike a little south of west. Following the topography across 6 S., 28 W., an anticline is crossed by the Saline in 6 S., 29 W., section 24. From here the axis is supposed to run south of west across 6 S., 29 W. Then turning west it crosses 6 S., 30 W., connecting with the anticline crossed by the Cossatot, in section 30, the southwest quarter of the northeast quarter. In section 29 this anticline forms a high ridge north of Sweeney's creek. Due west of this another anticline is crossed by the Rolling Fork in 6 S., 32 W., sections 25 and 27, and again in section 30, northeast of the northwest, an outcrop of igneous rock indicates its presence.

The White Oak Creek Anticline.—The White Oak creek anticline is the second of those crossed by the Little Missouri in 6 S., 29 W., section 12. The south side of the anticline appears, as a small monoclinal ridge, the single layer which forms the body of the ridge being bent sharply at the top. It then forms the ridge which runs south of west, south of White Oak creek and the Brushy fork of the Saline. This ridge, while not sharply defined, is quite a high one, forming a watershed between Brushy Fork and the drainage to the south and southeast. In 6 S., 29 W., it is crossed by the Saline in the southeast quarter of section 26, and again in the northeast quarter of section 33, the structure here appearing to be an overturn overthrown to the south. It then turns due west, forming a broad flat-topped ridge across the southern part of 6 S., 30 W., south of Hunter's creek, being crossed by the Cossatot in section 31, northeast quarter, the anticline still being overthrown

to the south. The high ridge between Sweeney's creek and Hunter's creek is a good example of a synclinal ridge. From the Cossatot the axis strikes a little south of west, the overturn flattens down and is crossed by the Rolling Fork in 6 S., 32 W., the southwest of the southwest of section 34.

The New Hope Anticline.—The third axis is crossed by the Little Missouri in 6 S., 27 W., in the southwest quarter of section 12. It appears to form the ridge upon which the western half of the Star-of-the-West and New Hope road is built. The lack of marked topography prevented its being followed further west.

The Self Creek Overturn.—In 6 S., 26 W., section 11, northeast quarter, is a good example of an overturn of the type shown by E'F' in Fig. 14. This is probably a continuation of an anticline crossed by Bear creek at the north township line of 6 S., 25 W., section 4. The strike would carry it south of west to a probable overturn in the top of Pine mountain south of Star-of-the-West, 6 S., 27 W., section 13. But the topography does not sustain that view. The steep north side of the Pine mountain in 6 S., 26 W., has a strike a little north of west. No outcrops were found in this part of the ridge and all those found in adjacent territory have a strike a little south of west, so that the ridge, though so marked, may not conform to the structure in 6 S., 26 W. West of Star-of-the-West the Pine mountain is deflected until it strikes about southwest, the strike of the outcrops being the same. It ends abruptly at Fallen creek.

The Gentry Overturn.—South of Gentry post-office is a ridge two miles long, starting in a high knob at the southwest corner of section 7, 6 S., 25 W., and maintaining a height of one hundred and fifty feet in a south of west direction to the Little Missouri river. This ridge gives the appearance of being an anticline overthrown to the north.

Bear Creek Anticlines.—An anticline is crossed by the Kirby-Murfreesboro road in 6 S., 25 W., in the southwest corner of section 11. In the northeast corner of section 19, on a small tributary of Bear creek, the dip suggests the presence of an overturn overthrown to the north; this may be a continuation of the Little Bear mountain overturn. In 6 S., 26 W., the Little Missouri crosses an anticline or overturn in section 24, the northwest quarter.

The Little Bear Mountain Overturn.—The Little Bear mountain overturn is in 6 S., 25 W. It begins in section 22, eastern part, at

the Kirby-Murfreesboro road. Rising abruptly to a height of about three hundred feet it runs at first northwest, then gradually swings around until it runs a little south of west and ends abruptly in the northwest corner of section 21. On the top of this ridge the rocks, though not rising into a wall, present very much the same peculiar structure as on the top of Antoine mountain. The sandstone on top of this ridge, when not examined closely, bears a striking resemblance to novaculite in color, fracture and general appearance. The structure is an overturn overthrown to the north.

Chimney Rock Anticline.—In 6 S., 26 W., section 36, southwest of northeast, a mass of rock juts out from the east bank of the Little Missouri, forming a perpendicular cliff one hundred and forty feet high and tapering from a broad base to a narrow top. It is known throughout the region as the "Chimney Rock." The dips along the river for a mile or two are within a few degrees of perpendicular, and so give no clue to the structure, but the most probable explanation is that the "Chimney Rock" is in the axis of a closely pressed anticline. Several anticlines may be crossed by the river in sections 25, 26 and 36 without their presence being recognized. One case on the west bank in section 26, southeast of northeast, where a mass of rocks having the same appearance as the "Chimney Rock," but on a smaller scale, is thought to be an anticline. The topography to the west strengthens this view.

The Chimney rock anticline, or some anticline very close to it, probably explains the structure of Jenkins' spring ridge, a high ridge running a little south of west across the southern row of sections of this township, and is also responsible for the high ridge to the east of the river. Evidences of an anticline appear in 6 S., 25 W., centre of section 27, on the Kirby-Murfreeeboro road.

Structure in Townships 7 and 8 South.

Silver Hill Anticlinal Axis.—In 7 S., 30 W., section 6, southwest quarter, the Cossatot crosses two anticlines, one at Antimony Bluff, and one about three hundred feet further north. In 7 S., 31 W., the topography indicates that one or both of them passes nearly due west, forming the high, flat-topped ridge upon which Silver hill is situated. In 7 S., 32 W., an overturn with a north dip is crossed by Robinson's Fork in section 8, northeast of the northeast. The topography between the two prongs of the Rolling Fork for several miles from their junction is extremely broken, but it shows the strike of the rocks.

Minor Anticlines.—In 7 S., 30 W., section 6, northwest quarter, a single exposure indicating an anticline was found on the Cassatot. In 7 S., 31 W., the Cossatot crosses two anticlines in section 12, one in the northeast of the northeast, and another in the northeast of the southeast. In 7 S., 32 W., the Rolling Fork crosses an anticline in the southwest quarter of section 15, near the mouth of Davis branch. It also appears to cross an overturn with north dips in section 16 east of the centre.

Cave Creek Anticlinal Axis.—In 7 S., 29 W., section 9, near the mouth of Cave creek, the Saline river crosses the Cave creek anticline. Going west it forms an unusually straight valley running a little south of west, down which Cave creek flows. This valley is continuous from the Saline to the Cossatot, but near the Cossatot it is deflected to the south, the axis appearing to be in a sharp ridge in 7 S., 30 W., the northwest quarter of section 20. This ridge ends abruptly in the northeast of section 20. In 7 S., 31 W., it forms the valley of a tributary of Stowe's creek, running through sections 22 and 23. It is here indicated only by the parallel outcrops of thin novaculite and siliceous shale. Through sections 19, 20 and 21 the axis is followed by Bellah creek, forming a broad valley to the Rolling Fork in 7 S., 32 W., section 27. The shales form bottoms on the Rolling Fork.

On the Saline river in 7 S., 29 W., section 16, its structure is that of a simple anticline. To the west, its structure could not be determined, but on Rolling Fork in 7 S., 32 W., low south dips of 10° to 15° point to a monoclinal structure. Fig. 31 shows the composite section exposed along the Rolling Fork.

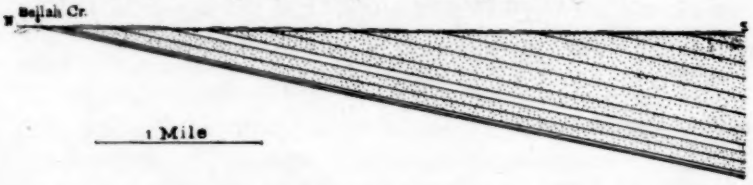


FIG. 31.—Section on Rolling Fork of Little river from Bellah creek southward.

The Blue Ridge Anticline—The topography strongly suggest that the Blue Ridge anticline is a continuation of the "Chimney Rock" axis which runs west through the Jenkins' spring ridge. Jenkins' spring ridge runs a little south of west to Fallen creek, and is cut by two creeks. At Fallen creek it is questionably anticlinal.

Then it runs due west to the New Hope-Centre Point road, where it turns a little north of west to the Muddy Fork. Here the structure is anticlinal. From Muddy Fork to Rock creek it has a south of west direction, and forms a high ridge in 7 S., 28 W.; in the southeast of the southwest of section 2 it forms a high knob. The anticlinal structure shows where the ridge is cut by Holly creek in section 9, northeast quarter, and by Rock creek in section 18, northwest quarter. From Rock creek west the high ridge continues, forming a prominent bluff where it meets the Saline in 7 S., 29 W., section 16.

The Arsenic Cave Anticline.—The Arsenic cave anticline was

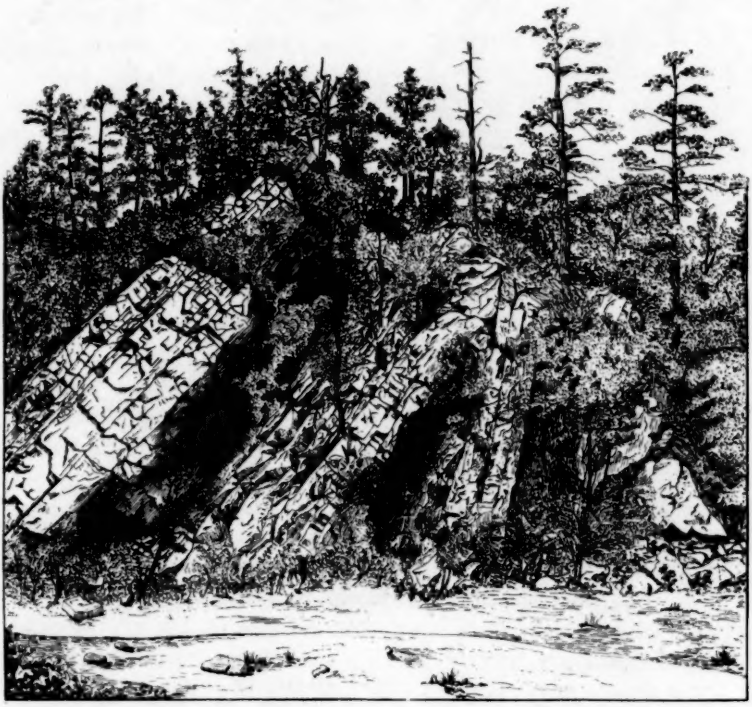


FIG. 32.—An overturned anticline at Arsenic cave on West Saline river (7 S., 29 W., section 21).

first noted by Mr. Purdue on Muddy Fork in 7 S., 28 W., section 12, northwest quarter. In section 9 it shows where cut by Holly creek in the southwest quarter of the southeast quarter. From

Holly creek to the Saline river it forms a high pointed ridge from two hundred to three hundred feet in height, the anticlinal structure showing in several places. At the Saline it is overturned, and where the axis crosses the river in 7 S., 29 W., section 21, northeast of southwest, there is a small cave known as Arsenic cave. Though the overturning does not show quite as plainly at the cave as in several places, this was the only point at which a photograph was obtained of the fold. Fig. 32 is a drawing from a photograph. This axis could not be followed west of the Saline, but it may have some connection with an anticline crossed by the Cossatot in 7 S., 30 W., section 33, in the northwest of the southwest quarter.

Another axis appears to run parallel to the Arsenic cave anticline but one-half mile south of it. This southern axis was found at three places. In 7 S., 20 W., it is crossed by the Muddy Fork in section 12, where it turns to the northeast, and by Holly creek in section 16, northeast quarter. No trace of it could be found on the Saline river. In 7 S., 30 W., it is crossed by the Cossatot in section 33 at the township line.

Other Anticlines.—In townships 7 and 8 S., 25 to 27 W., the structure is much obscured by the over-lying water-worn material and Cretaceous. An anticline is reported by Dr. Branner and Dr. Hay[1] as cut by Holly creek in 7 S., 28 W., section 28, northwest quarter.

Several minor anticlines show in the banks of the Cassatot in 8 S., 30 W., section 4, as shown in the Cassatot section, Pl. ii.

Red Bluff Anticline.—In 7 S., 25 W., a high ridge with a south of west strike makes what is known as Red Bluff where cut by the Little Missouri river in section 6, southwest quarter. The structure appears to be an overturned anticline with south dips. Following this strike in 7 S., 26 W., the dips give an anticline in section 8.

The Wall mountain anticline is shown by the topography to be continued across the northern row of sections of 7 S., 25 W., and south of Cow creek, but its extent to the west is unknown.

The Muddy Fork Overturn.—In 7 S., 25 W., section 10, northeast quarter, Prairie creek crosses what appears to be an overturned anticline with south dip. The topography strengthens this view. A high ridge which starts abruptly in section 12 crosses Prairie creek at this point and runs a little south of west to the Little

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 286.

Missouri. At places the top of the ridge is strewn with great monoliths due to the outcropping of a heavy layer of sandstone. In 7 S., 26 W., occur parallel lines of similar monoliths sometimes combining to form a low wall. These were found in the south half of section 16, and north half of section 21, and suggest a similarity of structure or continuity with the overturn exposed on Prairie creek.

In 7 S., 25 W., the Muddy Fork crosses an overturned anticline in section 20, northeast quarter just west of Muddy Fork post-office. The strike places this upon the same axis as the Muddy Fork fold.

Prairie Creek Anticline.—In 7 S., 25 W., Prairie creek crosses an overturn in section 28, northeast quarter. This is one of the few cases where an overturn can be traced as it folds over, then under. This anticline is exposed also in section 30 on the Little Missouri river.

Minor Anticlines.—In 8 S., 25 W., some evidence was found of an anticline crossed by Prairie creek in section 5 near the north section line, and by the Little Missouri in section 6, northern part.

In 7 S., 25 W., section 20, west of the centre, Mr. Hopkins describes the nose of a ridge which, at this point, is very suggestive of an overturn with dips to the south.

In 7 S., 26 W., section 30, a mile north of Nathan, the perpendicular dips indicate the presence of an anticline, and Dr. Hay[1] reports finding an anticline west of this on the Muddy Fork, near the Nathan-Muddy Fork road.

VIII. Theoretical Deductions.

In this chapter we shall discuss briefly some of the problems presented by the structure described in the preceding chapters.

Original Extent of Folded Strata.—A folded layer of rocks does not cover as much space as the same layer spread out, nor would it be a difficult problem to ascertain the difference, if the folds were completely exposed. When, however, it is remembered that we have only an imperfect section along practically a single line (not even a plane), and in addition to this many of the folds are overturned, or so closely squeezed that their upward or downward extension may be a few hundred feet or several thousand feet, and

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 284.

also that no correlation is obtainable in most cases, it is readily seen that the problem is a difficult one.

The following method was adopted for obtaining an estimate of the original extent of the folded strata upon the supposition that the folds are not broken, but remain complete until eroded.

North and south sections on the scale of one mile to the inch were made, as for example, down the Cossatot; the structure and dips accurately placed on it, and the folds theoretically completed, and then measured with a scale. The folds were made as short as could be done consistently, and the result may therefore be regarded as conservative. Still this method makes no pretense to accuracy, and the limit of error is certainly not more than twenty-five per cent.

The two best examples gave the following results: The Cossatot section, which is now twenty-four miles long, is estimated to have had an original length of thirty-five miles. The Antoine section, at present twenty miles long, is estimated to have had an original length of thirty-five miles.

If it be assumed that the movement took place from the south, the strata restored to their original horizontal position would spread over the territory now included in all of Clark, Pike, Howard and Sevier counties and the northern part of Nevada, Hempstead and Little River counties.

Had such a method been adopted as that used by Prof. Claypole in determining the original extent of a section across Cumberland county, Pa., there is little doubt that instead of thirty-five miles, we should have had between fifty and one hundred miles, as the sections on Antoine creek and Little Missouri river, with their many overturns, present much the same character of structure.[1]

Without going into a full discussion of the subject, we are led to conclude, that while there has been an apparent shortening of north-south cross-sections from their original position of not less than five or ten miles, and possibly much more, did we know the actual facts of the case, it is probable that such shortening has really been very small, and that the strata occupy nearly the same ground as that in which they were laid down.

Direction of Movement.—In determining the direction of movement three factors have been used: the dip of the axial plane of an anticline, or in the case of an overturn, the direction of over-

[1] Claypole, *American Naturalist*, Vol. xix, No. 3, March, 1885.

throw; the direction of dip of faults parallel to the strike; the general character of folding considered over the whole of the disturbed region.

Thus, in the case of overturns, if they are overthrown to the north, the dips being south on both sides of the axis, it is asserted that movement came from the south. In this region, however, we find overturns overthrown both to the north and south.

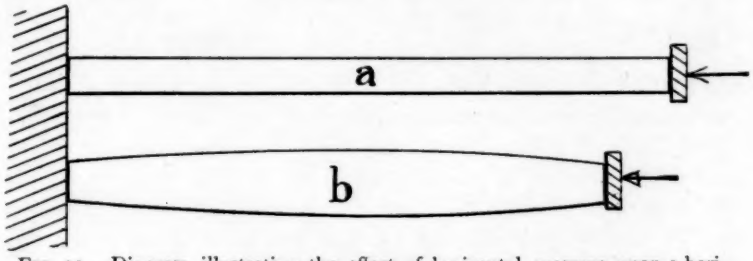
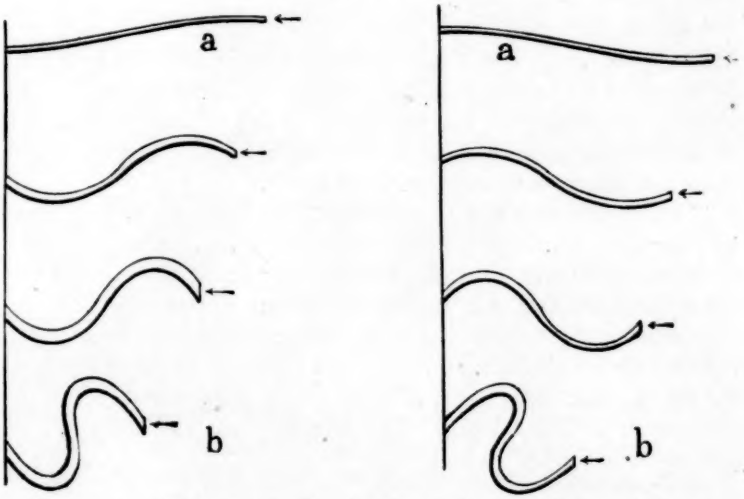


FIG. 33.—Diagram illustrating the effect of horizontal pressure upon a horizontal homogeneous bed.



FIGS. 34, 35.—Diagrams showing the effect of original dip upon ultimate structure.

An examination of the subject seems to show that the real determining factor in the direction of overthrow is the initial dip of the strata. Thus a perfectly homogeneous horizontal layer as in Fig. 33*a*

subjected to horizontal pressure, evenly applied, will not tend to bend, but to be compressed, as in Fig. 33*b*. If, however, as in Figs. 34*a* and 35*a*, it have a slight initial dip, the horizontal force will, at the point or points of bending, be resolved into two components, one tending to compress and the other to bend. Bending may then take place, but all that is desirable to note here is that, if the bending is carried to overturning, the direction of overthrow is not determined by the direction of movement, but by the direction of dip, as suggested in Figs. 34*b* and 35*b*.[1]

It is true that as a rule this dip will be toward the open sea, and the testimony of other elements show that, in many cases at least, the movement or apparent movement has been from the shore seaward. In such a case the overthrow will be away from the shore, and so there would be a tendency for the rule to hold good that the overthrow is away from the direction of movement. But we are led by the facts observed in this area where there exist overthrows both to the north and south to believe that such reasoning from the direction of overthrow is reasoning in a circle and not to be accepted as trustworthy.

Another element is the direction of dip of faults. This, too, contains the same objection, for, as shown by Daubree,[2] faulting parallel to the strike is governed by the folding, and if, as we are led to suspect, the folding is not entirely governed by the direction of movement, we must consider the faulting as under the same limitations and therefore not a trustworthy factor.

If a section across the Appalachians from southeast to northwest be examined, it will be noticed that the folding, which is intense at the southeast end, gradually becomes more and more gentle until at the northwest end the strata become horizontal.[3] An examination of Fig. 1, shows the same thing; in this case the intensity dies out from south to north. In such cases the evidence seems to be strong, that movement, if any, comes from the direction of greatest or closest folding. This suggests that the movement in our region was from the south.

[1] Dr. E. A. Smith has suggested the same explanation for overthrust and underthrust (*Am. Jour. Sci.*, April, 1893, p. 306), but as Mr. Ashley's paper was written before the publication of that paper his explanation is allowed to stand. —J. C. Branner.

[2] Daubrée, *Géologie Expérimentale*, Paris, 1879, p. 344.

[3] H. D. Rogers, *First Geological Survey of Pennsylvania, 1857.*

Bearing of Certain Features of the Region upon Theories of Mountain Making.—Reference was made in the description of Antoine mountain (p. 273) to the peculiar appearance of the layers where closely bent in the axis of the anticline. They have the appearance of having broken into blocks, and of these blocks having adjusted themselves to their neighbors. The rocks on top of Little Bear mountain present much the same appearance. In neither case do the rocks show noticeable metamorphism, though they are slightly closer grained than most of the layers.

Probably bearing on the same subject are the many cases noted where solid layers are sharply bent into acute angles without showing any sign of fracturing.

It has generally been assumed where such close folding without fracturing occurred that it was due to the confinement put upon it by the enormous vertical pressure of superincumbent beds. It being thought that, though the layer were under shearing stress far beyond its ultimate strength, the great vertical pressure would be sufficient to close every incipient fracture.

Some interesting experiments have been performed by Mr. Bailey Willis of the United States Geological Survey[1] in studying the effect of a horizontal pressure on soft layers under a weight of half a ton of shot. Some of these conditions were produced, and a study made of their action by graphical statics. Very similar results were obtained, but they led to certain questions presenting themselves.

If we assume such a series of layers under a gradually increasing horizontal pressure, the time will come when the bending component of that pressure at some point of initial dip will be sufficient to overcome the various resistances and forces opposing it, and the layer will begin to bend. If, when the layer has bent slightly, we make another examination of the components, forces and resistances involved, we shall find that the slight bending has given the bending component of the original horizontal pressure an advantage, and it has increased at the expense of the compressing component. On the other hand the resistances and forces opposing it remain about the same, hence its movement would be accelerated, and soon the bending would go forward with a rush until finally the horizontal pressure is transmitted across the fold instead of

[1] Bailey Willis, *Transactions American Institute of Mining Engineers*, June, 1892, xxi, 551–566; Thirteenth An. Rep. *U. S. Geol. Surv.*

along it. If the force not used up by the first fold were great enough other similar folds might be made.

Figs. 33 to 35 outline the action, only the main or combined forces or resistances being given in the figures. The conditions assumed are similar to those of Mr. Willis' (L) model (not given in the paper referred to). In this case the forces are only considered in reference to the main heavy layer, the others being assumed to be soft shales with little power of transmitting pressure. The question then arises, How can bending take place unless the bending component be as great as assumed at the moment when bending begins? A study of the rocks of Antoine mountain and elsewhere has led to this suggestion. May it not be accomplished by a much smaller force by introducing the factors of great length of time in connection with viscosity of solids?

It is now generally held that mountain making is a process of thousands of years, the movement being, as a rule, so slow as to be imperceptible, and yet we still cling to the idea that the forces and resistances involved are such as would be involved in rapid laboratory experiments. Thus a bar of stone is placed in the machine for testing the bending strength, and the result obtained is used in the study of mountain making.

Experiments have shown that solids under pressure below their ultimate strength but above their elastic limit will flow in the same way as will a plastic substance like putty. They have also shown that the elastic limit becomes lower when more time is allowed the pressure in which to act; and examples have been found of marble slabs, which have lain many years, bending[1] under their own weight without fractures, though when first placed in position they would not have bent under several times that weight, and would probably have broken before bending perceptibly. In Mr. Willis' experiments it may be that the plasticity of the materials made up for the shortness of time in which movement took place.

We are led to the conclusion that the folding may be due in part to flow of the cold solid rock under a comparatively small pressure continued over a great length of time.

[1] Winslow, *Am. Jour. of Sci.*, iii, Vol. xliii, p. 133. Ashley, *Proc. Cal. Acad. of Sci., 1893*, p. 319. See also Gibbs, *Am. Nat.*, Vol. iv, Jan., 1871, No. 11, Salem, Mass., p. 695.

IX. Post-Carboniferous History.

Period from Carboniferous to Cretaceous.

If in the sections of Pl. II the strata be restored above the surface, it will be seen that a great amount of erosion has taken place. The fact that the eroded upturned edges of the Carboniferous rocks have the Cretaceous rocks resting unconformably upon them is sufficient evidence that this erosion took place between Carboniferous and Cretaceous times.

What was the extent and character of this erosion? Mention has already been made of the peculiar character of the topography along the southern border of the area. Thus, if we start from the level Cretaceous country and travel north over the Paleozoic, selecting a road which avoids the immediate neighborhood of the larger streams, as for example, the county roads to Amity from Arkadelphia, from Hollywood, from Clear creek, from Murfreesboro, the Old Drove road north from Nathan, the old Stewart road from Atwood toward Galena and others, we cannot help noting as we leave the Cretaceous border and proceed northward that the almost level character of the country continues without break, except where small streams have made small valleys. The elevation increases from two or three to eight or ten miles when east and west valleys abruptly end the level surface. The lateral extent of this flat country is governed by the encroachments of the nearest streams on either side. In some cases where the tributaries of the south-flowing streams run east and west the level topography reaches out from the main divides and forms flat, minor east and west divides, which extend almost or quite to the south-flowing streams and form bluffs on those streams from 200 to 300 feet high. In short, the whole topography suggests an original surface nearly level, but rising gradually to the north and west over all the southern portion of the region. Into this streams have later cut their channels, in some cases to a depth of 200 to 300 feet, and in many cases have eroded the surface to such an extent that all vestiges of its original character are lost. The present northern boundary of this flat country is exceedingly irregular, but in a general way is indicated by the northward extent of the Post-Tertiary drift upon the roads mentioned above, as shown on the maps. How far north the Cretaceous extended is not known. A quarter of a mile

west of Star-of-the-West a single piece of Trinity limestone was found, and it is said that formerly such limestone was plentiful at that locality. In 7 S., 32 W., or 33 W., near the north township line limestone full of fossils is reported as occurring plentifully on a ridge west of Cross creek. This could not be verified. These suggest the possibility of the Cretaceous deposits having been originally laid down all over this region. This view is strengthened by the character of the Cretaceous deposits, limestones, chalks, etc., implying at least fairly deep waters over the region.

Cretaceous and Tertiary Periods.

During the Cretaceous and Tertiary periods the southern part of Arkansas was the theatre of several gentle oscillations of level which find record in the varying deposits bordering on the south.

For the details of this history the reader is referred to the Survey's reports on the Mesozoic and Tertiary.[1]

We must, however, note the land epochs, as it was probably during one or all of these land epochs that the present drainage systems of our region were inaugurated and fixed. Two have been noted during the Cretaceous and another follows the Tertiary subsidence.

Frequent references have been made to the way the main drainage streams cut across the structure, being influenced by the strike of the folds only to a minor degree. In the novaculite area this feature of the larger streams is still more marked, the Little Missouri and Cossatot being good examples. In some cases these streams cut across high ridges, when, by a short east or west offset, they could have run around them.

Remembering that the Cretaceous strata were originally much thicker than they now are, if we replace these deposits, which have a gentle south dip, they would doubtless extend well northward toward or to the Ouachita mountains. Supposing now the movement of elevation takes place. These new strata would gradually become a land surface. Streams would start from the point of highest elevation and run seaward. If a map of western Arkansas and eastern Indian Territory be examined, it will be found that there is such a centre from which drainage flows in all directions. This centre is in the neighborhood of the Rich mountains, at the

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, p. 182; Rep. for 1892, Vol. ii.

western end of the Arkansas base line. To the north runs the Poteau river, to the northeast the Fourche la Feve, to the east the Ouachita, to the southeast the Caddo and Little Missouri, to the south the West Saline, Cossatot and Rolling Fork, to the southwest the Mountain Fork of the Little river, and to the west the Black Fork of the Kimishi river.

We may then assume that that region was the centre of elevation for the land period that gave rise to the present drainage.

We can readily imagine a condition of things, such as at present exists in the Cretaceous region, having previously existed over the whole area. The creeks and rivers following the general slope of the Cretaceous strata, entirely unaffected by the buried Paleozoic sandstones. Then as they sink their channels until the Paleozoic strata are reached, they find it easier to continue sinking their beds than to force their banks and make new channels conformable with the softer rocks.

If next, we suppose that, due to shore conditions, the thickness of the beds diminished to the north, we can understand how erosion would first expose the Paleozoic strata at the north and the line of contact would gradually move southward until it reached its present position.

As erosion began to cut deeply into the Paleozoic strata, the minor streams yielded to the influence of structure and became in time structural streams, and the larger streams, though maintaining their first courses in a general way, became conformable to the structure in minor details of their courses.

In which of the land epochs the present drainage originated and became fixed we do not know. It must be remembered that these land periods each produced a nonconformity in the Cretaceous and Tertiary rocks, so that it is not impossible that all the effects of erosion during one land epoch may have been erased in the next subsidence, new beds being laid down and the next land epoch beginning a new system of drainage. However this may have been, the evidence seems to show, that, at the end of the land period following the Tertiary, the topography of most of our area was much as it is to-day, therefore it will be discussed at this point.

Drainage of the Area.—The direction of the main streams would be represented diagrammatically by drawing radiants from the centre of drainage at the western end of the Arkansas base line.

PROC. AMER. PHILOS. SOC. XXXVI 155 U. PRINTED AUGUST 12, 1897.

To the northeast of the Caddo are four smaller creeks, Blakely creek, Prairie creek, Bayou Delile, DeRoche creek. Between the Caddo and the Little Missouri are Terre Noir creek and Antoine creek. The still smaller creeks are shown on the maps. As a rule, the tributaries run at right angles to the main streams. Thus, the Caddo runs nearly east, its tributaries nearly all run south, and this same relation can be traced with but few exceptions to the Cossatot, which runs south, but has east and west tributaries.

Going from east to west the general elevation increases more rapidly on the north edge of the maps than on the southern; consequently the difference of elevation between points on the north and south edges of the maps is greater in the western part than in the eastern.

The effect of this is quite marked, both upon the character of the streams and upon the topography; this is still further intensified by the direction of the streams in the eastern part, giving them the advantage of the longest side of the slope. Thus the Caddo and other streams in that region may be characterized as a succession of long, deep pools connected by short rapids having only a few inches, fall. Further west the Cossatot and Rolling Fork are, for much of their courses, shallow, rapid streams with but few stretches of quiet water.

Comparatively speaking all the streams are rapid. The more western streams probably averages between fifteen and twenty-five feet fall to the mile; the Caddo has a fall of seven or eight feet to the mile.

In the same way the topography changes from east to west. In the east it consists of broad valleys with many bottoms along the streams. In the west the valleys are narrow, deep and steep-sided. In the Cretaceous area the smaller streams are mostly surface streams not having cut channels of any great depth. This, to a large extent, is also true of the smaller streams of the Caddo valley, though, where their courses compel them to cut across ridges, they become more rapid and have abrupt banks. In the western part, where the tributaries as a rule follow structural lines, they sink their beds rapidly in the shaly strata, producing deep, narrow ravines, and where these are quite numerous, the topography becomes exceedingly broken.

The Overwash Gravels.

Spread over both the Cretaceous and Carboniferous areas is an overwash of gravels, sands and occasionally a little yellow clay. These deposits are of great thickness along the northern edges of the Cretaceous rocks, while, as a rule, they are but thin on the Carboniferous beds. These gravels and cobbles are well-rounded or flattened fragments of novaculite of almost every color, from black to white, yellow being most common, followed by gray, red, brown and a mottling of these. Sandstone boulders are also mingled with the novaculite pebbles. These water-worn boulders vary from the size of one's fist down, but occasionally they are as large as one's head. Sometimes a hillside is covered with the novaculite boulders bleached so white that they resemble snow.

Sometimes the gravels are cemented together by iron, forming a conglomerate. Sometimes beds of considerable thickness are thus cemented, as, for example, near Wolf Creek P. O., on Wolf creek, Pike county.

The character of the overwash gravels is well illustrated in a fresh cut near the depot at Arkadelphia on the side of the road running north to the business part of the town.

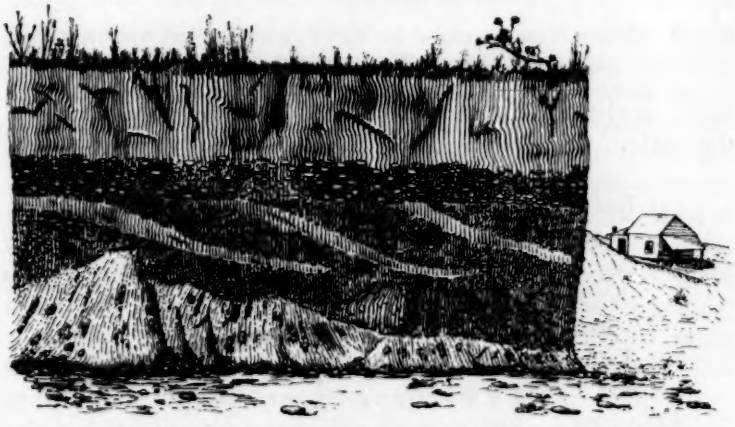


FIG. 36.—Section of gravel bed near the railway station at Arkadelphia.

	FEET.
(*a*) A layer of sandy clay, red, mottled with gray, at the bottom all gray, at the top all red.....	3½
(*b*) A layer of yellowish red gravel from very fine to the size of a hen's egg or larger.....	1½

	FEET.
(*c*, *d*) A bed of fine gravel (*c*) into which there run thin layers (*d*) of sandy clay without gravel, the fine gravel being the size of a pigeon's egg and smaller	4
(*e*) Talus to level of road	2–4

As the cut was but a few days old when noticed, it seems highly probable that the red color at the top of (*a*) is due to the oxidation of the iron, the color where freshly exposed being gray; the gradation from the pure gray at the bottom to the deep red at the top exhibits very nicely the process of oxidation.

The relation of the bed of firm sand to the other beds of that period is shown on Antoine creek in 8 S., 23 W. In section 14 it forms a ten-foot bluff for a thousand feet, overlying two or three feet of gravel.

At the Antoine crossing of the military road to Fort Towsen and

FIG. 37.—Section at the crossing of the Fort Towson road and Antoine creek (8 S., 23 W., section 24).

above, section 24, it appears again, Fig. 37 being a cross section at that point. We have:

	FEET.
(*a*) Bed of gravel dipping east or southeast and lying on a soft, friable sandstone dipping 45° south	8
(*b*) Bed of firm sand with same dip	8
(*c*) Outcrop on east bank of soft yellow or brown sandstone dipping 70° south, 25° west	3–5
(*d*) Thin bed of novaculite gravel	2
(*e*) Bed of very firm sand	8–10
(*f*) Gravel	?

The age of the sand in this case depends somewhat on the age of the uppermost gravel, which is evidently the younger. But the gravel on top may be a very recent deposit made by the creek.

The beds of gravel attain no great thickness in the Paleozoic

region. In the northern part they usually consist of scattered boulders, all the finer material having been removed. At the northern edge of the area, over which it still exists in an undisturbed condition, it is comparatively thin. But going southward it gradually increases until, at Centre Point, there is an exposure of seventy-five feet of it in a bluff. Mr. Hill estimates that a mile south of Centre Point it has a thickness of two hundred feet.[1]

The undisturbed gravel deposits occupy an irregular area on the west side of the Ouachita river for a mile or two from the river, and from a mile south of Social Hill to Rockport. They occupy all of 6 S., 19 W., except the northwest corner. Passing westward the northern escarpment follows the Chalybeate mountain in an irregular line through 20 west, swinging south in ranges 21 and 22 west, it crosses range 23 west about in the centre of 7 south. It reaches this far north in each range to the west until the West Saline has been crossed, west of which gravel was only noted in spots.

North of this line gravel was found in nearly every township east of the West Saline river, occupying areas from five or six square miles down to a few acres.

Generally these consist of scattered boulders of water-worn novaculite; some show a little fine material as though they represented fragments of undisturbed deposits.

All the beds of the creeks which rise among the novaculite ridges contain more or less water-worn novaculite gravel, but in those in the northeast part of the region this gravel sometimes constitutes the valley bottom, the creek cutting down through it, and in places exposing a thickness as high as six feet. Prairie Bayou, Big Hill and Valley Fork of Point Cedar creek are examples of this kind. In the centre of a large curve in the Caddo in 5 S., 23 W., section 22, northwest quarter, the deposit of gravel reaches a depth of thirty feet. It is not probable that these are original undisturbed deposits, but remains of a subsequent deposit, made when erosion carried the gravel from the higher ground and filled the valleys faster than the streams could carry it off.

In 5 S., 28 W., section 24, Mr. Purdue found two elliptical knobs or mounds one hundred feet or more long and fifty feet high, which, to all appearances, seemed to be made up entirely of novaculite water-worn gravel. One of them is known as Round mountain.

Distribution in Other Regions.—Without asserting an exact cor-

[1] *Geol. Surv. of Ark.*, Ann. Rep. for 1888, Vol. ii, p. 40.

relation, it may be said that there occur deposits of approximately the same age and of the same character in Alabama, Mississippi, Texas and Indian Territory.[1]

Age of the Gravel.—No fossils have been found in these gravels, so that the only determination of their age possible is by their stratigraphic position. They lie unconformably on the Paleozoic and Cretaceous. Similar gravels overlie the Tertiary, and are therefore of more recent origin, and on that account the age of the gravels is given as Post-Tertiary.[2]

X. Economic Geology.

Minerals and Stones.

Minerals.—Many have been led by the disturbed condition of the layers all over this area to think that mineral of some kind must exist here in quantity. Much prospecting has been done and many thousands of dollars expended in sinking shafts and prospect holes, but all without results, except in a small belt in the northern part of Sevier county. For convenience it may be well to consider first this belt which is known as the antimony district.

The Antimony District.

The ores found in this district have been discussed in the Survey's report on Gold and Silver, to which the reader is referred.[3] As Prof. Comstock misinterpreted the structure in this district, it may be well to state that more fully.

Extent of the Antimony District.—As defined by localities in which ore has has been found, the antimony district lies entirely in

[1] Tuomey, *Second Biennial Report on Geology of Alabama, 1858*, p. 144. Hilgard, *Report on the Geology and Agriculture of the State of Mississippi*, 1860, pp. 3–46. Hilgard, *Amer. Jour. of Sci.*, May, 1866. *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, pp. 43–47.

[2] Mr. Ashley's paper was written before the publication of the report on the Tertiary of Arkansas by Professor Harris. The latter author has, in my opinion, solved the problem of the age of these gravels. He regards them as shore deposits "laid down under similar conditions, though by no means in the same geological epoch," and he thinks that their "rearrangement presumably took place before the close of the epoch represented by the underlying stratified beds." See *An. Rep. Geol. Surv. Ark.* for 1892, Vol. ii, 7–9. *The Tertiary Geology of Southern Arkansas.* By Gilbert D. Harris.—*J. C. Branner.*

[3] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. i, p. 136, *et seq.* See also Wait, *Trans. of Am. Inst. of Mining Eng.*, Vol. viii, 1879–1880, pp. 42–52.

township 7 S., ranges 29–32 W. inclusive; in 7 S., 29 W., however, the Busby mine is the only place where ore was found. Thus it may be said to be about twenty-four miles long by four miles wide, and has a very slight south of west trend, occupying the northern part of the eastern townships and the central part of the western.

Prospectors report finding traces of stibnite north of this region, but as in no case has it seemed to warrant the expenditure of time or money in exploitation, the district may be considered as fully comprehended in the limits given.

Structure of the District.—The structure in this district is obscure, the topography is broken, and outcrops of bedded rock are scarce. Such structure as was obtained was derived partly from exposures in shafts and prospect holes. As shown in the Cossatot section of Pl. ii, there appear to be about half a dozen anticlines in the district, though only half that number could be found on the Rolling Fork and on the West Saline. As shown in the section, the anticlines are closely folded, giving many high dips. No evidence of faults, which play such an important part in Prof. Comstock's interpretation of the structure, was found, but this must be considered as having only a negative bearing, as faults doubtless do exist all through this region. The Silver Hill anticline or anticlines have a strike of less than 5° S. of W. The Cave creek anticlinal axis has a strike of from 5°–10° S. of W.

The rocks in the districts are the same as all over the region—shales, shaly sandstones and sandstones. The thin bedded novaculite occurs in such a way as to suggest that, if the strata under it are Silurian, then the Silurian is extensively exposed in this belt, if indeed it be not the predominating formation.

Character and Occurrence of Ore Deposits.—The ore deposits of this district are in the form of bedded veins. While they usually follow the bedding in strike and dip, they frequently run at small angles to the dip, and it is claimed that in a very few cases small deposits are found crossing the bedding, but none were seen. They occur mostly in shale, but though a contrary claim was made, they were also found in sandstones at several places. The veinstone is quartz and varies from a thin layer, in which the quartz simply forms a matrix for fragments of the country rock, to veins four feet thick and very pure. The ore occurs as lenticular masses in the quartz from two inches to twenty-two inches thick, and occa-

sionally of considerable extent, as one mass is said to have yielded over seventy-five tons of clean stibnite. This quartz veinstone is frequently exposed at the surface as a low wall, and in one case in 7 S., 32 W., sections 8 and 9, this is easily traceable for nearly a mile. The veins are of such a character that there is always much uncertainty about the occurrence of paying ore. A shaft at the Valley mines has been sunk 230 feet and still shows good ore, while others have run out in a short distance below the surface.

Along the Rolling Fork exploration revealed twelve ore-bearing veins within two miles. In the region just south of Antimony City it is claimed that five leads or veins have been found.

Similar quartz veins are common north of this tract in townships 5 and 6 S., but no ore has been reported from them.

Ores.—The main ore and the only ore as yet found in paying quantities is stibnite. Silver and lead are found in small quantities. In still smaller quantities or occurring only as traces were found sphalerite, cervantite, jamesonite, pyrite, chalcopyrite, arsenopyrite, tetrahedrite, and a few others.

Ores Outside of the Antimony District.—There are a few places north of the antimony district where the general appearance of quartz veins suggests a similarity of conditions to those found in the antimony district. But, with these exceptions, the remainder of this Paleozoic area does not give evidence of containing ore of any kind in any quantity; in fact, in view of the careful prospecting that has been done and the negative results obtained, strengthened by a study of the geology of the region and the character of the rocks, the evidence seems to be against the existence of pay ore in the region.

Silver.—During the silver excitement a few years ago all the northern edge of this territory in the eastern part was thought to be included in the silver district, and a large portion of it was taken up in claims. Much prospecting was done and many shafts were sunk, but no one reports finding any silver, or getting an analysis that gave more than a trace of it.

Very recently a prospect hole has been started just north of Caney Fork P. O., based upon the finding of two or three small pieces of silver at that point. One of the pieces seemed to be almost pure silver, about the weight of a dollar. It had evidently been run out and worn smooth; it was certainly not as it came from the earth, though still in the condition in which it was found. The

finding of Indian "tools and hammers" in the same locality might explain the presence of the silver. For the tools are undoubtedly Indian implements, such as are found all over the region, and instead of suggesting an old mine, suggest a camping place. The silver belonged to the Indians and was brought from nobody knows where.

Traditions of rich silver mines are plentiful, but they always go so far back and contain so many improbable factors that they may be dismissed as of no value except to entertain the traveler.

Lead.—Lead is often reported as having been found in the region. The localities given, though not definitely known, were all in the Caddo valley. It is possible that a little lead may occasionally be found, though the geology makes it appear improbable that it should ever be found in any quantity.

Manganese.—The northern portion of the region borders on the manganese district of southwestern Arkansas, and in a few instances traces of manganese were found on anticlines well in the centre of the region.

The ore, in quanties sufficient to color the joints in the sandstone, is quite common. Occasionally it occurs in small masses as a conglomerate or mixed with iron. The original bed, or more properly plane of occurrence, is a bed at the top of the novaculite series. It partakes of the same folding as the novaculite, and will be found, not as a level bed, but as an outcropping edge of the layer parallel to the neighboring novaculite layer, and, except as modified by the topography, usually running along the side hill of a novaculite anticline.

The ore occurs in pockets difficult to mine and generally in very small quantities. Those interested in the manganese of this part of the State should consult the Survey's report on manganese.[1]

Iron.—Iron as a commercial ore does not exist in this territory. A few loose pieces of impure bog iron ore occur especially around the chalybeate springs, where the sandstone is highly impregnated with iron. With these exceptions iron exists here only as the coloring and cementing material of the red and brown sandstones and conglomerates. Iron is sometimes found in the same bed as the manganese, but as such deposits are properly north of the area in every case, the reader is referred to the Survey's report on iron.[2]

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. i.
[2] *Geol. Surv. of Ark.*, An. Rep. for 1892, Vol. i.

Salt, Soda.—Though indefinite reports of salt having been found in the region were frequently heard, all those that could be traced out proved to have come from wells or springs in the Cretaceous border on the south.

Soda is said to exist as an efflorescence in a cave on the Little Misrouri in the northern part of 7 S., 25 or 26 W.

Summary of Mineral Prospect.—As far as shown by exploration and exploitation up to the present time, paying ore has been found only in a small belt in northern Sevier county, and but one ore, stibnite, has been found in that district in paying quantities; though silver and lead ores have been found in small quantities. In speaking of stibnite as a paying ore, it is meant that it might be remunerative under more favorable conditions of transportation, smelting, etc. In the present state of things no reliable judgment could be given on the future of the antimony interest in this region. Whether the ores exist in quantity, or whether the richest deposits have already been exhausted, are questions that cannot be answered without a more thorough examination of the detailed geology of the antimony district than the State Survey could undertake. The output in 1890 was 54,188 pounds, but in August, 1892, none of the mines were being worked.

Commercial Stone.

Building Stone.—It is possible that the ferruginous varieties of sandstones may prove of value as building stones: they dress easily and acquire a firm surface afterward, but on account of their brown color it is hardly probable that such stone, even though its wearing qualities be good, will ever be very popular.

There occasionally occurs locally a form of the sandstone, both pleasing in appearance, and, judging from weathered fragments, of good wearing quality. It is a slightly metamorphosed white or light gray sandstone, and varies from a sandstone hardly altered to an almost pure quartzite, the harder varieties, however, being too hard to work easily and therefore of less value. A typical outcrop occurs on Winfield creek, just below the junction of the east fork in 7 S., 21 W., section 10, northwest quarter. An outcrop on Antoine mountain in 6 S., 23 W., section 19, and one reported by Mr. Hopkins on Prairie creek in 7 S., 25 W., east of the centre of section 10, might be mentioned, and numerous other small outcrops were noted.

Considering the great extent of country to the south and east without building stone of any kind, it was hoped that stone of value would be found in this, the nearest of the rock-covered mountain country. At present rock is used here only for lining chimneys, the ferruginous sandstone and slabs of laminated sandstone being used for the purpose.

Millstone Grit.—Grits have been noted and described in preceding chapters. Rock of this kind is fairly abundant, but it is only here and there that it is firm enough to be used as millstones. Quite a number of these have been cut from it, several having come from the outcrop on top of the Chalybeate mountain just west of the Caddo river in 6 S., 20 W., section 14.

It is claimed by some that the meal ground with these stones is always gritty, and whether for that or some other reason, there are, as far as could be learned, none of the millstones running at present.

Grindstones.—A few attempts have been made to cut grindstones from the sandstone. None of these were seen, however, nor could it be learned just what kind of sandstone was used. Some stones were obtained from the part of the Chalybeate mountain east of the Caddo, whence that portion of the mountain took the name of Grindstone ridge. Similarly Grindstone creek, a tributary of Antoine creek in 8 S., 23 W., section 15, took its name from the occurrence there of a gritty sandstone from which grindstones have been made.

Slates.—The only places where slates give promise of any value is along the Rolling Fork in 6 S., 32 W.; and west of there near the State line, Owen reports good slate.[1] But it is doubtful if these have sufficient value to pay for working.

XI. Agriculture, etc.

Soils.

The soils of the region are of three kinds:

1. The red and brown soils of the overwash gravels.

2. The residuary soils formed by the decomposition of rocks in place.

3. The alluvial or river bottoms soils. These will be taken up in this order.

The Overwash Soils.—The overwash soils consist of gravel and

[1] Owen, Second *Geol. Surv. of Ark.*, p. 112.

sands with some clay. As shown by analysis, they are lacking in lime, and, over much of the region, the proportion of gravel to sand is so large as to make the land of little value with present modes of farming.

However, when the value of fertilizers becomes recognized, it is probable that this section, with its level yet well-drained areas, will form some of the most desirable agricultural land in the region.

At present a great forest of pine with some hard woods covers nearly the whole exposure of the overwash; there are but few farms and habitations on it at present.

Residuary Soils.—Residuary soils are those formed by the decomposition of the underlying rocks, and, as in this region these rocks are mostly sandstones, we have little else than sands with some clayey sands in the valleys.

Almost universally these soils have been enriched by the decaying leaves of the all-prevailing forest. This gives, when first cleared, considerable fertility, but as fertilizers are for the most part wholly unknown, or unthought of, this richness lasts but a few years. There is no doubt but that this soil, primarily rich, may, by proper care and the use of fertilizers, be made not only to maintain indefinitely its fertility, but even to become more productive with time. Proof of this exists in the very rare cases where some one does use fertilizers, with the result of every year raising twice as much to the acre as any of his neighbors, and each year leaving the land in better condition than the year before.

Alluvial Soils.—The alluvial soils form the bottom land along all the streams of any size. They are the cream of the agricultural lands. The reason for this is that they not only combine all the elements found in the other soils, but the rich vegetable mould, which in the residuary soils forms a layer on top, is here disseminated from top to bottom, so that they retain their fertility a long time. The idea so generally held that they will retain their fertility indefinitely is of course not correct.

The bottom lands are generally flooded lands upon which the river has for long periods deposited its load of silt and mud, until, having changed its course or deepened its channel, the land is left suitable for use. They are lacking in lime, as no lime is touched by the depositing streams. A few of them are still subject to overflow in highest water, which, to some extent, renews their fertility.

Amelioration of Soils.—Fortunately the work of Geological Survey

has shown that in the Cretaceous region there are extensive deposits of gypsum, marls and chalks containing the elements needed by these sandy soils.[1]

The present methods of farming require that new clearings be frequently made and new fences built. The same amount of labor, expended in fertilizing, would increase crops, and increase the value of land.

Timber.

Timber is at present the greatest latent source of wealth, and in consequence of the roughness of much of the region it will always play a considerable part in the sources of income. In the southern half of the region, where the Pleistocene gravel occurs, the timber is mostly pine; in some districts it is exclusively so, except in the creek bottoms. In the rest of the region both pine and hard wood are found, the latter being the more abundant and consisting largely of oaks.

This mountain timber is said not to be as even-grained as that growing in the bottoms, but has less sap and greater durability.

Of the oaks, the white oak is most abundant; red oak, post oak and others occur less frequently. The short-leafed pine is probably more abundant than any other single species of tree, especially over the gravel-covered area of the southeast, where magnificent forests of it are common. Sweet and black gum are plentiful in the southern and eastern part, and in the same part of the area is much holly. Cedar has been plentiful along the Cossatot and Rolling Fork; ash, hickory and many other valuable woods are well scattered over the region. As before stated, the whole area is one vast forest except for the few clearings made for cultivation.

At present, from lack of transportation facilities,[2] these forests have only a nominal value. But the timber near the railroad is being cut so rapidly that already the lumbermen are beginning to reach into this area. For this reason timber here has a prospective value sufficient to make it worthy of careful saving. At present it is treated in a most wasteful manner.

Relation of Geology to Culture.—The relation existing between the portions of a region under cultivation to the geology of the region is seldom more interestingly shown than in this area. The

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, Chaps. xxii–xxvii.

[2] This report was written before the construction of the Kansas City, Pittsburg and Gulf Railway through the western part of Arkansas.—*J. C. Branner.*

two factors in the geology are the shales and shaly sandstones and the structure which governs the exposures of these shaly layers. The shaly layers for a number of reasons being favorable for cultivation, the structure that brings the shales to the surface brings culture.

If on a map of the region all the land under cultivation were shaded, it would be found that instead of being irregularly scattered, the shaded portions would run in belts, some narrow, others broad, while between them in several places would be belts of almost entirely unshaded territory, sometimes several miles broad, and from twenty-five to seventy-five miles long.

These broad belts of unsettled territory are frequently nearly level, or but slightly rolling, but they are mostly uplands. The one feature which distinguishes them is that they are outcrops of the great sandstone beds which form the upper portion of the columnar section of the Paleozoic strata of this area.

The strips of well-populated country run east and west, following the structure, and as they are almost exclusively confined to the valleys, the valley features of the topography will be briefly reviewed.

On the eastern sheet the largest valley is the Caddo valley, contained mostly in township 5 S., and running from the Ouachita river to the divide between the head waters of Antoine creek and the Little Missouri river. It is enclosed on the north by the Trap mountains and Brooks mountain, and on the south by the Chalybeate mountain and its continuation westward. Its main stream is the Caddo, and in it is contained the best farming land in the area, as well as the largest villages.

Notice the arrangement of the post-offices in this valley. On the Prairie Bayou anticline are Social Hill and Saunder's. South of them lie, in a line, Maddry, DeRoche, Bismarck, Valley, Point Cedar and Big Elm, not all on the same anticline, but on the major anticline.

At its western end the Caddo valley is broken into four minor valleys by three ridges: Rock Creek valley just north of Pine mountain; Antoine valley between Pine mountain and Big Bear mountain; Woodall valley between Big Bear mountain and Antoine mountain, and Walden valley between Antoine mountain and Straight and Wall mountains. The valleys in each case take their names from their main streams and are all well settled.

South of the Chalybeate mountain is a well-marked valley, known as the Chalybeate valley. This is wedge-shaped, with the point at Antoine creek in 6 S., 23 W., section 34, widening out to the east between the Chalybeate mountain and the high ridges in the north tier of sections of 7 S. At the eastern end it opens out and merges into the flat country in that direction. Its principal streams are those forming the head waters of the Terre Noir.

Caney Folk valley is an east and west valley a little further south. Starting from the head of Caney Fork of Antoine creek, 7 S., 24 W., section 7, it runs east, becoming lost in the level country north of Hollywood. From west to east it is bounded on the north by Wall mountain, Straight mountain and the ridges south of the Chalybeate valley, and on the south by the high east and west ridges which form the north edge of the old base level in the centre of 7 S., 21–24 W. It is followed all the way by the Arkadelphia-Murfreesboro road. In the area covered by the western sheet no such marked valleys occur. There are, however, a few belts, sometimes of indefinite limits and extent. They generally represent major anticlines, on which may be several minor anticlines. In these cases the folding as a whole is such that shales have been quite freely exposed, and it is along these belts that the land has been taken up and in which most of the settlements occur, so much so that, if the land under cultivation were indicated on the map, it would quite fairly outline these structural features as previously suggested.

Such a belt usually occurs just south of the novaculite ridges, as between Warm Spring and Brooks mountains on the north and Pine mountain on the south. It is indicated by the post-offices: Rock Creek, Wilson, Lodi, Langley, Port Logan and Ethridge. This is but an extension of the Rock Creek valley above mentioned.

The Antoine valley extension of the Caddo valley runs north of the Bear mountains and the Pine mountain in 6 S. To the north it extends toward the Pine mountain south of Rock creek. In the western part of 6 S., 27 W., the western extension of this valley is joined by a continuation of Woodall valley and then runs a little south of west. It is bordered on the north by White Oak creek and Silver Hill anticlinal axes, and on the south by Blue Ridge anticlinal axis and Cave Creek anticlinal axis. This belt follows the structure and shows the same lithological characters over the whole distance; in fact the same as those along the same strike to

the Ouachita river. Kirby, Gentry, Star-of-the-West, New Hope and other settlements lie through the centre of this valley.

To the north of this belt the Brushy Branch anticlinal axis exposes shales and produces a low and well-inhabited area.

The Galena and Little Possum creek anticlines in like manner are not productive of strong topographic features and are well under cultivation.

Water Power.—Most of the larger streams carry some water all the year round. In the eastern part, however, the larger streams present but few opportunities for obtaining water power; though in a few places, as on the Caddo, where the stream makes a long and close bend or horseshoe, power might be obtained by carrying water over the neck at some narrow place.

In the western part the streams have more fall and opportunities for obtaining power are frequent. Many small mills and cotton gins exist there already. In many places the topography is such as to render the building of dams of twenty or thirty feet height, a comparatively simple problem. There are no falls of more than a few feet, unless the Falls of the Cossatot be counted such (the stream here drops between twenty and thirty feet by a series of small jumps in a space of less than a quarter of a mile), but in many places where ridges are cut through, the channel is narrow, giving facilities for building dams, while the fall is so rapid that but little land would be flooded by back water.

With the utilization of such cheap power there is no reason why cotton and other products, instead of going south to the railroads and then north to the mills, should not here be converted into cloth and other manufactured products.

Mineral Springs.—Several mineral springs have become quite well and favorably known as summer watering places for people from south Arkansas, Louisiana and Texas. The best known of these are:

Mineral Springs in 8 S., 22 W., section 18.
Jenkins' Springs in 6 S., 26 W., section 34.
Baker's Springs in 5 S., 30 W., section 14.
Gillam Springs in 4 S., 30 W., section 22.
Tyra Springs in 5 S., 32 W., section 2.
Bog Springs in 5 S., 32 W., section 10.

All of these springs are pleasantly located. At the present time the Mineral Springs in Clark county and Jenkins' Springs are the

only ones much resorted to. The former is described in the Survey's report on mineral waters.[1]

Mineral Springs, Clark county, are two miles northeast of Antoine post-office, a quarter of a mile south of the military road, immediately on the Amity-Okolona road. Seven springs issue near each other and one larger spring a short distance away. These springs are well tiled and the large one has a cover. The water issues from a dark-colored, sandy deposit, with streaks of black shale or clay, all of which are probably of Cretaceous age. These beds dip to the south at an angle of 45°. The place is used as a local summer resort and camping place. An open Methodist Chapel, a dozen or more summer cottages and frames for a number of tents have been built at this locality.

The others have all been largely resorted to. For the past few years it has been claimed that there have been as many as five hundred people spending more or less of the summer at Baker's Springs. The principal constituents of these springs is given by Owen[2] as follows:

Analysis of Baker's Sulphur Spring Water.

"Carbonate of alkali, which is probably in the state of carbonate of soda.

"Chloride of sodium.

"A small quantity of free sulphuretted hydrogen.

"Traces of sulphate of soda and magnesia.

"When boiled down it exhibits strong alkaline properties. Its medical properties are a mild laxative; a diuretic, antiscorbutic, slightly alterative and strongly antacid. This spring rises from the slate at the base of a ridge of quartzose sandstone.

"There are also several other mineral springs in this neighborhood, in Polk county. One at Samuel Gray's on section 20, Township 5 north, Range 29 west, its temperature 58°, the air being 52° (also known as Shurd's Sulphur Spring, G.H.A.). The main characteristic constituents of this water are:

"Carbonate of soda.

"Chloride of sodium.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1891, Vol. i, p. 111.

[2] *Second Geol. Surv. of Ark.*, 1860, p. 97.

"Sulphuret of sodium.

"Traces of sulphate of soda.

"Traces of sulphate of magnesia.

"Its medical properties will be found to be analogous to those of Baker's Spring.

"Nathan Aldridge's Sulphur Spring contains the same constituents, only differing slightly in the proportions."

As shown in Pl. ii, these springs all rise from the same layer of shale.

The principal constituents of the Gap Springs are given by Owen as:

"Chloride of sodium.

"Sulphate of soda.

"Sulphate of magnesia.

"Bicarbonate of alkali.

"And probably a little sulphuret of alkali.

"A trace of carbonate of lime."

An examination of the so-called alum spring gave indications of the same ingredients, with the exception of the absence of sulphur, the presence of iron and a larger proportion of sulphates. These waters will have a mild, aperient effect, combined with a slight alterative action on the system."

Tyra springs in 5 S., 32 W., section 2, consist of a number of springs on the north bank of a small tributary of the Rolling Fork of Little river just west of Hatton Gap. The south bank and bed of the stream are novaculite, so that they appear to come from a layer of shale immediately overlying the novaculite.

Bog Springs are located in the pass of Cross creek through South or Bog mountain on the west side of the creek. They flow out from the foot of the mountain only a few yards from the creek. The principal spring forms a considerable bog.

As a rule, this area of Carboniferous rocks is well supplied with springs, and the streams are remarkably clear and the waters soft.

Stated Meeting, May 21, 1897.

Vice-President PEPPER in the Chair.

Present, 32 members.

The Proceedings of the Officers and Council were submitted.

Pending nominations Nos. 1376 to 1388 were read and, except No. 1380, action on which was postponed, were spoken to. Secretary Frazer and Dr. Morehouse were appointed tellers, and an election for members was held.

Dr. Morehouse read an obituary of the late Lewis A. Scott, Esq.

Mr. Prime offered the following resolution, which was adopted:

Resolved, That a Committee of three be appointed by the President to consider and report on the advisability of offering to coöperate on behalf of this Society with the Royal Society of England in the preparation of an International Catalogue Raisonné of all scientific publications, and that such Committee shall be authorized to communicate with the Committee of the Royal Society on this subject."

Mr. George F. Edmunds made a communication on International Arbitration, which was discussed by Dr. Pepper, Mr. Wharton and Mr. Edmunds.

Dr. William H. Furness, 3d, then made a verbal communition, entitled, "Further Glimpses of Borneo," with lantern slides.

A paper by Dr. Charles E. Sajous on "Solar Heat and Universal Gravitation—A New Working Hypothesis," was then read.

Dr. Greene, on behalf of the Library Committee, offered the following resolutions:

That authority be given to the Library Committee to present one of the duplicate copies of the Treaty of Peace with Great Britain, printed in Paris in 1783, to the library of the Department of State, and one to the Historical Society of Pennsylvania, if they do not already possess copies.

Adopted.

That authority be given to the Library Committee to extend the time after one o'clock, during which the Library shall be open to such hours as they may see fit, provided that no additional expense be incurred.

Adopted.

The Tellers of Election reported that the following Candidates had been duly elected to membership in the Society:

Lord Lister, London.
Prof. W. C. Roentgen, Würzburg.
Owen Wister, Philadelphia.
Samuel N. Rhoads, Philadelphia.
Fridtjof Nansen, Lysaker, Norway.
Stewart Culin, Philadelphia.
S. F. Peckham, Ann Arbor.
Charles F. Mabery, Cleveland.
Edward Orton, Columbus, O.
Prof. Theodor Tschernyschew, St. Petersburg.
Prof. A. Karpinsky, St. Petersburg.
Theodore N. Ely, Philadelphia.

Dr. Hays offered the following resolution:

That a Committee of five be appointed by the Chair to consider and report upon the present status of the Magellanic Premium, and whether anything can be done to more fully carry out the original intentions of its founder.

Adopted.

The Society was then adjourned by the presiding officer.

INTERNATIONAL ARBITRATION.

BY HON. GEORGE F. EDMUNDS.

(*Read May 21, 1897.*)

The subject of international arbitration is becoming more and more interesting, and possibly, in view of its latest developments, somewhat more difficult of realization.

The idea of arbitration, whether between individuals or nations,

necessarily implies a state of difference in respect of rights or duties. In the municipal State these rights are established or defined by municipal law, either written or unwritten, and they are compulsory in the sense that the aggrieved individual may appeal to the power of the State to compel a recognition of his rights or a redress for his wrongs.

This principle is equally true in respect of its nature as between sovereign and independent States, with the exception that there is no common tribunal yet established which has the authority to decide upon, and much less compel obedience to, these principles.

The idea, therefore, of international arbitration presupposes that there must be some rule or law that is to be the standard by which to measure the disputed rights or duties that may be drawn in question between sovereign States.

These rules or laws are what we call international law. It is not founded in any essential sense upon the same grounds as is municipal law, for that is founded upon the assumed consent of all the people who compose an organized State to which they have given the authority, through their representatives of whatever kind, to declare what their conduct toward each other shall be.

International law, therefore, which is to be administered through international arbitration, unless there be special provision made in an agreement for arbitration other or further than what international law requires, is really and in its widest aspects the law inherent in the nature of man; that is natural law, as it is called by the writers. And this natural law may be reduced to its last and best analysis in the statement, which is the foundation of all practical religion, that every man and nation should do to another that which he or it would wish another to do to himself or itself.

But the law of nations has undergone—as have the social conditions of mankind in the long centuries that have preceded us—a great improvement. Some of the earliest writers on the subject have undertaken to defend the use of poisoned weapons in war; later writers have been shocked at such propositions, as, justly, they should have been. An interesting and comprehensive discussion of the nature and history of natural and international law was given by Vattell a century and a half ago, and it may be found in the Preface to the comparatively recent editions of his treatise on the law of nations.

I affirm (notwithstanding the doubts in this respect of very emi-

nent and able gentlemen expressed within a year or two) that there is such a thing as international law that is just as binding upon independent nations in every sense as is municipal law upon the individuals composing a State. It is true that this international law cannot be adjudged in particular cases by a preëstablished tribunal or executed by a sheriff or constable. But it is not the less binding upon the moral sense or honor (if there be any difference in the expression) of every nation having relations with another.

The progress of civilization has been such that nations have come more and more to feel the necessity of, and their obligation to obey, the fundamental principles of justice that every one will admit exist between individual men in a state of nature. Men in a state of nature have found that they could not exist safely and make progress without the establishment of associations respecting common rights and duties which we call States. Thus associated, they bear the same relations as States to each other that they bore toward each other in a state of nature; that is, the duties of justice and right. In their formation of States as between each other, they have agreed to establish tribunals to determine rights and to establish authority to compel respect of such rights. The law of nations imposes the same duties and obligations between nations, but it lacks the compulsory power referred to.

This state of things, then, leads at once, and logically, to international arbitration.

I think no one can state a difference in principle between the duties of men toward each other in an organized State and the duties of nations toward each other, although they do not have a federation possessing the power of judgment and coercion through tribunals appointed to decide and powers authorized to execute the decision.

Thus, in the present condition of the world, international arbitration is the only resource short of the *ultima ratio regum* through which disputes between nations that shall have failed to be adjusted through diplomatic means can be determined.

Why is it that it so often happens that arbitration in the place of war does not take place? It is obviously for the reason that the various organized nations of the world are so suspicious of each other that they are not willing to submit their differences to any common tribunal in the brotherhood of nations.

Take, for illustration, the present condition in eastern Europe

and western Asia. The United States, having no possible selfish interest (just or unjust) in the question, might have been appealed to in the person of their chief magistrate to decide, upon due hearing and consideration, what were the respective rights of Greece and of Turkey in Crete, and what were the respective adjustments that ought to be made in respect of European interests in the passage from the Black Sea to the Mediterranean, and in the passage from the Mediterranean to the Red Sea. Had the powers interested in this most difficult question been willing to submit to the United States, or to any other unbiased power, or to a tribunal composed from several States, these perpetual and burning questions which continually involve not merely public war but animosities affecting large communities, unmeasured disaster of life and peace and property might have been avoided. And so it is everywhere in all the frictions and differences that exist in the relations of independent States. The fundamental difficulty is in their want of confidence in each other. The Senate of the United States, I am grieved to say, has very recently demonstrated this want of confidence in any tribunal of an international character to which it should be willing to refer differences even of a very narrow range that might arise between ourselves and that power whose colonies and dependencies are everywhere, and upon whose flag the sun never sets. It may be that motives and considerations less broad than those I have stated have led Senators, as it is reported, to refuse assent to the recent arbitration treaty with Great Britain. And, if this be so, there may be ground for the hope that at some near day in the future this great nation will not be content to rest itself alone on its physical strength, but upon the justice of its cause determined by arbitration in many matters of difference that may arise with another nation, and that in such a case it will be willing to believe and to act upon the belief, that strength is not the absolute test of justice and right, and that the strongest power may sometimes be in the wrong; and, therefore, be willing—strong as it may be—to have its disputes determined by impartial international judges, rather than by the arbitrament of war, with all its miseries.